THE NATIONAL WINDSTORM IMPACT REDUCTION PROGRAM: STRENGTHENING WINDSTORM HAZARD MITIGATION

HEARING

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

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THE NATIONAL WINDSTORM IMPACT REDUCTION PROGRAM: STRENGTHENING WINDSTORM HAZARD MITIGATION

THURSDAY, JULY 24, 2008

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:06 a.m., in Room 2318 of the Rayburn House Office Building, Hon. David Wu [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
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The Subcommittee on Technology and Innovation

Hearing on

The National Windstorm Impact Reduction Program: Strengthening Windstorm Hazard Mitigation

Thursday, July 24, 2008
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witness List

Dr. Sharon Hays
Associate Director
White House Office of Science and Technology Policy (OSTP)

Dr. Marc Levitan
Director, Hurricane Center at Louisiana State University
Associate Professor, LSU Department of Civil and Environmental Engineering

Ms. Leslie Chapman-Henderson
President and CEO
Federal Alliance for Safe Home, Inc. (FLASH)

Dr. Timothy Reinhold
Senior Vice President for Research and Chief Engineer
Institute for Business & Home Safety (IBHS)

HEARING CHARTER

SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The National Windstorm Impact Reduction Program: Strengthening Windstorm Hazard Mitigation

THURSDAY, JULY 24, 2008
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

The purpose of this hearing is to review the activities of the National Windstorm Impact Reduction Program (NWIRP) and to examine the role of R&D in saving lives and reducing property losses from windstorms. The witnesses will also discuss advancements in wind hazard mitigation and methods of transferring the results of research into practice for code developers, builders, and property owners. Lastly, the witnesses will provide testimony on the priorities for a reauthorization of NWIRP, which expires in fiscal year 2008, and any changes needed to increase the effectiveness of the program.

2. Witnesses

- **Dr. Sharon Hays** is the Associate Director of the White House Office of Science and Technology Policy (OSTP);
- **Dr. Marc Levitan** is the Director of the Hurricane Center at Louisiana State University (LSU) and an Associate Professor in the LSU Department of Civil and Environmental Engineering;
- **Ms. Leslie Chapman-Henderson** is the President and CEO of the Federal Alliance for Safe Home, Inc. (FLASH)
- **Dr. Timothy Reinhold** is the Senior Vice President for Research and Chief Engineer at the Institute for Business & Home Safety (IBHS).

3. Brief Overview

- Hurricanes, tornadoes, thunderstorms, and other severe wind-related weather can claim lives, cause injuries, and cause billions of dollars in damages. In 2007, according to the National Weather Service, 111 Americans died in tornadoes and thunderstorm winds, and this year, tornadoes have already killed 119 people. The economic impact of the 2004 and 2005 hurricane season alone totaled over $160 billion. As more people move to vulnerable coastal areas, these losses are expected to increase.
- The National Windstorm Impact Reduction Program (NWIRP) is a federal program which includes the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the National Institute of Standards and Technology (NIST), and the Federal Emergency Management Association (FEMA). The objective of NWIRP is to decrease the loss of life and property from windstorms through research and development on weather phenomena and mitigation techniques. Created in 2004, the program has received little attention from the Administration. Expenditures for R&D related to NWIRP, as reported by the Administration were approximately $7.5 million in total since FY 2004.[1] This amount is well below authorized levels. The

[1] This figure does not include expenditures by the National Science Foundation (NSF). Spending levels from NSF on NWIRP related activities are unavailable.

participating agencies have also failed to coordinate the ongoing wind hazard related R&D through other mechanisms.

- Reports from the National Research Council (1999) and RAND (2003) argue that a well funded, coordinated R&D framework could reduce wind losses. The RAND report, commissioned by OSTP, analyzed federal disaster-related R&D funding and found that the majority of this money supported short-term weather prediction. The report recommended that the balance in funding shift toward R&D for long-term mitigation measures. Despite this recommendation, the federal R&D portfolio has not been rebalanced to adequately fund research on windstorm impacts and mitigation measures.
- Mitigation efforts can reduce losses to wind-related disasters significantly, but these measures are not widely adopted in hazard prone areas. Barriers to adoption include high capital cost, the lack of financial incentives, and a lack of knowledge by property owners.

4. Background

High winds in hurricanes, tornadoes, thunderstorms, and other weather phenomena cause significant damage to buildings and infrastructure. Annually, such weather is also responsible for an average of 124 American fatalities[2] and over 1,600 injuries. Though better building practices have resulted in fewer fatalities in recent decades (Table 1) total direct property losses in the U.S. from 1996 to 2006 are over $160 billion (in 2006 dollars). Moreover, costs associated with wind-related natural disasters have doubled or tripled each decade over the past 35 years. Much of the precipitous increase in property losses is due to the rise of population in vulnerable coastal areas. Between 1980 and 2003, the number of Americans living in coastal counties increased by 28 percent. More than 50 percent of Americans now live on the coast and this upward trend is projected to continue.[3] Those dwelling in manufactured housing (i.e., mobile homes) are at an increased risk of death, injury, and property loss from high-wind storms.

Table 1. Fatalities, injuries, and property losses. Data compiled by the National Weather Service (available at: http://www.nws.noaa.gov/om/hazstats.shtml). Property losses reported in millions of USD.

YEAR	Tornado Fatalities	Thunderstorm and High Wind Fatalities	Tropical Cyclone Fatalities	Tornado Injuries	Thunderstorm and High Wind Injuries	Tropical Cyclone Injuries	Tornado Property Losses	Thunderstorm and High Wind Property Losses	Tropical Cyclones property Losses
2006	67	40	0	990	382	1	752.3	503.6	1562.4
2005	38	23	1016	537	228	130	421.8	457.2	93084.4
2004	35	42	34	396	312	840	537.1	3468.1	18561.6
2003	54	47	14	1087	362	233	1268.8	522	1879.5
2002	55	45	51	968	416	346	801.3	372.7	1104.4
2001	40	31	24	743	439	7	636.1	351.6	5187.6
2000	41	51	0	882	468	1	423.6	248.2	8.1
1999	94	62	19	1842	473	10	1959.5	408.2	4190.1
1998	130	65	9	1868	955	77	1714.2	1498.4	3540.6
1997	67	75	1	1033	561	33	730.7	241.8	887.6
1996	25	64	37	705	448	22	719.6	326.3	1430.1

In 2004, Congress passed the *National Windstorm Impact Reduction Act* (P.L. 108–360) which established NWIRP. The objective of the program, as stated in the enacting legislation, is "the achievement of major measurable reductions in losses of life and property from windstorms" through a coordinated Federal effort. The Act directs NOAA, NIST, NSF, and FEMA to support activities to improve the understanding of windstorms and their impacts, and to develop and encourage the implementation of cost-effective mitigation measures to reduce these impacts. The statute charges an interagency working group (IWG)—chaired on a rotating basis by FEMA, NSF, NOAA, or NIST—to coordinate the R&D priorities, portfolio, and budget. The program is authorized through FY 2008 (Table 2).

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[2] Average calculated from National Weather Service fatality data for 1996 through 2006, exclusive of 2005 hurricane season deaths.

[3] 2003 RAND Report: *Assessing Federal Research and Development for Hazard Loss Reduction,* Charles Meade, Megan Abbott.

Table 2. Funding Authorized for NWIRP

Agency	FY 2006	FY 2007	FY 2008
FEMA	8.7	9.4	9.4
NSF	8.7	9.4	9.4
NIST	3.0	4.0	4.0
NOAA	2.1	2.2	2.2
Total	22.5	25.0	25.0

As required by legislation, OSTP submitted an NWIRP implementation plan to Congress in April 2006. The plan assessed programs relevant to the goals of NWIRP across eight federal agencies and identified important areas of research that were not covered by current activities. The knowledge gaps covered the three broad categories of research authorized in the Act: understanding windstorms; assessing the impacts of windstorms; and mitigating the effects of windstorms. To further the understanding of windstorms, the plan identifies the need for research on the structure of windstorms and wind behavior, instrumentation for the study of windstorms, and the development of standards for deploying instruments, assessing measurements, and storing and sharing data. Research into assessing the impacts of windstorm would include the response of structures to windstorms and their resilience over time, and social science research on the impact of windstorm damage on communities, particularly vulnerable populations. For mitigation, research is needed to improve building codes and standards, and to develop better decision-making tools for all level of government.

The implementation plan also recommends that an IWG within the National Science and Technology Council's (NSTC) Committee on Environment, Natural Resources Subcommittee on Disaster Reduction oversee the research portfolio outlined above, with representatives from NSF, NIST, NOAA, and FEMA, as well as NASA, the Federal Highways Administration (FHWA), and the Army Corps of Engineers. These agencies support mission-related R&D on windstorms and windstorm impacts. The IWG would be responsible for facilitating communication between the agencies on the best means of allocating agency resources to meet NWIRP goals and for coordinating this federal research portfolio.

As of the FY 2009 budget request, the Administration has never requested funding for NWIRP. Although the implementation plan recommended an IWG coordinate a research portfolio targeted to the identified research needs, there has been little effort to do this. Currently the IWG is not chaired by any agency, as required by statute, nor has OSTP convened an external advisory committee to provide guidance and feedback for the program.

Program activities related specifically to wind-hazard reduction are not explicitly stated in agency budgets, however, the Administration reports that agencies have funded approximately $7.5 million (not including NSF) in related activities since FY 2004. These efforts are summarized below:

- **NSF's** role in NWIRP is to support basic research on engineering and the atmospheric sciences to improve the understanding of windstorms and their impacts on the built environment and lifelines. To that end, NSF has funded research in the atmospheric dynamics that form storms and hazardous winds; post-Hurricane Katrina grants to document and preserve data on the built environment, perform social science research, and to fund engineering studies; and research to gain a better understanding of evacuations and community rebuilding. Estimates from NSF on the total spending related to NWIRP are unavailable, but the agency estimates they will spend $6.8 million on research related to NWIRP in FY 2008.
- **NOAA's** role in NWIRP is to support atmospheric sciences research to improve the understanding of windstorms and their impact on the built environment and lifelines. Aligned with NWIRP's goals, NOAA performs education and outreach related to hazards through Sea Grant institutions and other means; supports research and operations at the National Weather Center for improved prediction and monitoring of severe storms and hazardous winds; gathers field data on hurricane dynamics; develops probes and other monitoring equipment for data collection in extreme weather; develops decision

support tools that map wind-speeds; provides information and planning assistance to increase community storm resiliency; and participates on the U.S.–Japan Panel on Wind and Seismic Effects. **NOAA reports spending of $3.5 million on NWIRP related activities for the period of FY 2004 to FY 2008.** The NOAA FY 2009 budget request includes $1 million for these activities.

- **NIST's** role in NWIRP is to support R&D to improve building codes, standards, and practices for design and construction of the built environment and lifelines. Activities that NIST has engaged in related to NWIRP include the development of software and procedures to facilitate the use of automated wind impact sensors on buildings; computational tools for determining realistic wind loads on the built environment; methodologies for predicting ultimate structural capacities; post-Hurricane Katrina evaluations of the built environment; providing technical information to improve codes and standards; and participating on the U.S.–Japan Panel on Wind and Seismic Effects. **NIST reports spending of $2.45 million on NWIRP related activities for the period of FY 2004 to FY 2008.** The NIST FY 2009 budget request includes $1.4 million for these activities.
- **FEMA's** role in NWIRP is to support the development of risk assessment tools and the effective mitigation techniques, windstorm related data collection and analysis, and conduct public outreach and information dissemination to promote mitigation measures. Activities identified by FEMA that meet these goals include: update and development of HAZUS, a modeling tool for communities to estimate damage, economic loss, and social impacts of storms; Mitigation Assessment Teams (MAT) studies of building performance after major storms; construction guidance for building in vulnerable coastal areas and storm shelters; and cooperation with NOAA to improve evacuation planning for hurricanes. **FEMA reports spending of $1.5 million on NWIRP related activities for the period of FY 2004 to FY 2008.** FEMA estimates spending on these activities for FY 2009 to between $200,000 and $250,000.

In 2003, the RAND Corporation released a report commissioned by OSTP to assess federal spending on disaster-related R&D. The study found that the majority of such funding goes to fundamental research into atmospheric and meteorological aspects of windstorms and other weather. A significantly smaller portion went toward structural engineering R&D on buildings and other infrastructure to increase their resilience during and after windstorms. The RAND report recommended that the R&D focus shift toward long-term mitigation efforts. The report stated, "This is especially relevant for weather related hazards, for which R&D is primarily limited to procurements for short-term forecasting efforts," noting that short-term prediction efforts can have a life-safety impact but generally do not reduce property or economic losses. A 1999 National Research Council report[4] recommended that: "the Federal Government should coordinate existing federal activities and develop, in conjunction with State and local governments, private industry, the research community, and other interested stakeholder groups, a national wind-hazard reduction program. Congress should consider designating sufficient funds to establish and support a national program of this nature." Experts in mitigation argue that support for windstorm hazard mitigation could result in similar benefits to those generated by the National Earthquake Hazard Reduction Program (NEHRP). This program, created by Congress in 1978, is a coordinated interagency effort to reduce the impact of earthquakes on the built environment and communities. Researchers in both fields (wind and earthquake engineering) often point to the minor damage from the 2001 6.8 Seattle earthquake as evidence that thirty years of funding earthquake engineering R&D have had measurable results.[5]

Measures to mitigate damage from windstorms are currently available, but they are not universally adopted. A study published in 2008 by the Wharton Risk Management and Decision Process Center at the Wharton School of Business quantified the impact of mitigation, showing that mitigation efforts could reduce hurricane-related losses by 40 to 60 percent. Similarly, post-storm FEMA MAT reports consistently show that houses built to modern codes generally remain standing through a storm, compared to those not built to code. A natural tendency to ignore or downplay the risk of catastrophe could explain the lack of adoption of mitigation measures however, other barriers, such as the high cost of implementation and limited

[4] 1999 National Research Council Report: *Review of the Need for a Large-Scale Test Facility for Research on the Effects of Extreme Wind on Structures.*

[5] 2003 RAND Report: *Assessing Federal Research and Development for Hazard Loss Reduction,* Charles Meade, Megan Abbott.

financial incentive (through reduction in insurance premium, tax incentives, etc.), and a lack of understanding of risk and available mitigation technologies also prevent more wide spread use of mitigation measures.

5. Issues and Concerns

- The costs associated with windstorms are rising, but little funding has gone toward understanding windstorms and their impacts and developing mitigation measures. Reports from the National Academies, RAND, and OSTP's NWIRP Implementation Plan strongly recommend a coordinated effort for R&D to reduce hazards from windstorms. The limited research that NSF, NIST, NOAA, and FEMA have supported is not well coordinated. For example, although NIST, FEMA, NSF, and several other federal agencies dispatched resources to examine the effects of Hurricanes Katrina and Rita, there is little evidence that these activities were coordinated.
- As stated in the 2003 RAND report, to achieve a reduction in the massive economic losses from windstorms, the federal R&D portfolio should support long-term research on hazard reduction methods. Based on the funding levels for NWIRP reported by the Administration, this type of research is not adequately supported at the federal level. Researchers in the wind engineering community point to a consistent lack of funding as a cause of the decline in the number of graduate students and professors in the wind engineering profession and as a hindrance to advancing knowledge that would have useful applications in reducing losses from windstorms.
- Mitigation techniques do exist to save lives and reduce damages but they are not universally adopted. Decreasing the cost of mitigation measures and increasing the education and outreach to property owners could increase the adoption of mitigation techniques.
- The authorization for NWRIP expires this fiscal year (FY 2008). To date, the program has not been well implemented. Changes to the legislation and the program should be considered if the reauthorized NWIRP is to be an effective program.

Chairman WU. Good morning, and welcome to this morning's hearing on *The National Windstorm Impact Reduction Program: Strengthening Windstorm Hazard Mitigation.* This is a very, very important topic. The Nation has learned that, and I have learned that in my own Congressional district.

Every single year, severe winds from hurricanes, tornadoes, and thunderstorms damage or destroy thousands of homes and businesses. They damage vital infrastructure, and most importantly, they threaten human life. On average, 60 Americans die in tornadoes each year, but this year is already proving to be one of the deadliest years on record for wind-related fatalities, with over 100 Americans killed in tornadoes this spring alone. And we cannot forget the more than 1,000 people who lost their lives in Hurricane Katrina and the follow-on consequences.

Dollar amounts vary widely on the extent of property damage and economic losses from windstorms, but since 2004, windstorms have cost this country well over $160 billion.

We in the Pacific Northwest were reminded last December that no part of the country is safe from severe windstorms. On December 1, 2007, a Pacific storm brought hurricane force winds and heavy rain to Oregon and Washington, and tragically, five people died in that storm. Thousands were left with damaged homes and flattened communications systems and electrical grids. Insurance claims for Oregon alone, for non-flood-related damage in that windstorm, were over $70 million, and local and State officials have sought $53 million in federal money to help repair damaged infrastructure. Knowing that these types of storms will strike again, we must do more to prevent the loss of life and property.

Today, we will discuss the National Windstorm Impact Reduction Program, or NWIRP. It was created by Congress in 2004 to help reduce devastating losses from windstorms. NWIRP directs four federal agencies, FEMA, NOAA, the National Science Foundation, and NIST, to conduct coordinated R&D on the nature of windstorms, their effects, and on ways to mitigate impact. The program also calls on these agencies to facilitate technology transfer, to make sure that beneficial research is put into practice.

Since passage of the enacting legislation, the program has done, quite frankly, little to address this very substantial problem. Unfortunately, NWIRP has received little attention from the Administration, in terms of either funding or coordination. NWIRP expires this fiscal year, and if we are to reauthorize it, we will need to discuss how it can be changed to ensure that it meets its goals of improving the safety of Americans and increasing protection from wind hazards. Damage from storms is projected to increase as a greater number of Americans move to coastal areas, and especially those areas which are subject to violent windstorms.

We are not completely powerless to reduce losses from windstorms. Known mitigation techniques can greatly decrease the amount of wind damage, in some cases, by as much as 50 or 60 percent.

I look forward to our witnesses' comments on improving the National Windstorm Impact Reduction Program, and I also hope they can suggest how we can improve the utilization of existing windstorm mitigation technologies and practices.

And at this point, I would like to recognize the Subcommittee's Ranking Member, Dr. Gingrey, for his opening statement.

[The prepared statement of Chairman Wu follows:]

PREPARED STATEMENT OF CHAIRMAN DAVID WU

Good morning, and welcome to today's hearing on *The National Windstorm Impact Reduction Program: Strengthening Windstorm Hazard Mitigation.* This is an incredibly important topic. Every year, severe winds from hurricanes, tornadoes, and thunderstorms damage or destroy thousands of homes and businesses, harm vital infrastructure, and, most importantly, threaten human life. An average of 60 Americans have died in tornadoes each year since 1996, but 2008 is already proving to be one of the deadliest years on record for wind-related fatalities, with over 100 Americans killed in tornadoes this spring alone. And we cannot forget the more than 1,000 people who lost their lives in Hurricane Katrina. Dollar amounts vary widely on the extent of property damage and economic losses from windstorms, but since 2004, economic windstorms have cost the country well over $160 billion.

We in the Northwest were reminded last December that no part of the country is safe from windstorms. On December 1st a Pacific storm brought hurricane-force winds and heavy rain to the Oregon and Washington coasts. Tragically, five people died in that storm. Thousands of people were left with damaged homes and vital infrastructure, including communications and electrical systems, were badly damaged. Insurance claims for Oregon for non-flood related damage were over $70 million and local and State officials have sought $53 million in federal money to help repair damaged infrastructure. Knowing that these types of storms will certainly strike again, we must do more to prevent the loss of life and property.

Today we will discuss the National Windstorm Impact Reduction Program, or NWIRP. Created by Congress in 2004 to help reduce devastating losses from windstorms, NWIRP directs four federal agencies—FEMA, NOAA, NSF, and NIST—to conduct coordinated R&D on the nature of windstorms and their effects and on ways to mitigate their impact. The program also calls on these agencies to facilitate technology transfer to make sure that beneficial research is put into practice. Since passage of the enacting legislation, the program has done little to address this very sizable problem. Unfortunately, NWIRP has received little attention from the administration in terms of both funding and coordination. NWIRP expires this fiscal year, and if we are to reauthorize it, we will need to discuss how it can be changed to ensure it meets its goals of improving the safety of Americans by increasing the protection from wind hazards.

Damage from storms is projected to increase as a greater number of Americans move to coastal areas. However, we are not completely powerless to reduce the losses from windstorms. Known mitigation techniques can greatly decrease the amount of wind damage—in some cases by as much as 50 to 60 percent.

I look forward to our witness' comments on improving the National Windstorm Impact Reduction program. I also hope they can suggest how we can improve the utilization of existing windstorm mitigation technologies and practices.

I now recognize the Subcommittee Ranking Member, Dr. Gingrey, for his opening statement.

Mr. GINGREY. Mr. Chairman, thank you, and before I start my opening statement, I want to ask that Dr. Tim Reinhold's testimony be added, his written testimony, to the record. He was delayed, detained, snowed in, I don't know what the situation is in Chicago, rainstorms more likely, but was not able to get here. So, with unanimous consent, we can add his testimony to the record. (*See Appendix 2: Additional Material for the Record.*)

Chairman WU. Without objection, so ordered.

Mr. GINGREY. Thank you, Mr. Chairman, and good morning.

I want to thank you, of course, for calling this hearing on an issue that unfortunately touches the lives of the American people on an annual basis, damage and economic loss from windstorms. Each year, lives are lost, and billions and billions of dollars are spent recovering from the destruction caused by tornadoes and hurricanes.

When the *National Windstorm Impact Reduction Act* was passed four years ago, the Federal Government recognized the need to proactively conduct research and development programs to save lives and reduce property damage caused by these horrific storms. I am looking forward to hearing from today's panel about both the success of the National Windstorm Impact Reduction Program over the past years, as well as improvements, as the Chairman said, to the program that can be made as we move forward.

Mr. Chairman, my home State of Georgia has had a long and notorious history with tornadoes and windstorms, with several incidents in the past year. In fact, in March of 2007, tornadoes stuck the towns of Potterville, North Newton, and Americus, Georgia, leaving nine people dead and tremendous damage in their wakes. In December, in Ashburn, a truck driver was killed when a tornado blew his vehicle off the road. This past March, and you may have read about this on the sports pages, downtown Atlanta witnessed incredible damage to infrastructure when tornadoes ripped holes in the roof of the Georgia Dome during the 2008 Men's, SEC Men's Basketball Tournament. It is amazing, amazing that we didn't have a tremendous loss of life, because all of those people were slow to evacuate, and to stop the game they were all interested in watching.

At the same time, in my Northwest Georgia district, the 11th of Georgia, a tornado struck Polk and Floyd Counties, causing significant economic loss, and regrettably, taking the lives of two of my constituents, one in Floyd County, one in Polk County, Bonnie Turner, Jerry Albers, salt of the Earth people from farming communities. Their homes were destroyed, but sadly, they lost their lives as well.

In addition to the lives lost, the United States sustains billions of dollars in economic damages each year due to tornadoes and hurricanes, and vulnerability is only increasing, it would seem. According to the Georgia Insurance Commission, insured losses across our state, in just the first five months of this year, have surpassed $400 million.

Mr. Chairman, improved windstorm impact reduction measures have the potential to save lives and reduce losses associated with these storms. For instance, the Federal Government continues to invest in R&D activities that can increase warning time for tornadoes and any other extreme weather events. While little can be done, as you have said, to protect structures from large tornadoes, researchers have made significant progress in designing buildings and retrofits to withstand high wind events. Finding practical and effective applications for this research remains the biggest challenge at the National Windstorm Impact Program today.

This obstacle is unfortunately complicated by the number of stakeholders. The Chairman mentioned the four agencies, federal agencies, State and local communities, private organizations, all have a role in better preparing the Nation against windstorms. The R&D efforts in this program create ways for these stakeholders to collaborate in a productive and an effective manner.

Mr. Chairman, I want to thank these three witnesses, and the fourth that was not able to be here, through no fault of his own, for coming to relate their expertise on the challenges and hopefully, the successes of reducing windstorm impacts. This is a complex challenge with clear benefits that will require a great deal of cooperation, patience, and resolve to overcome. And I certainly look forward to supporting these efforts, and I yield back to you.

[The statement of Mr. Gingrey follows:]

PREPARED STATEMENT OF REPRESENTATIVE PHIL GINGREY

Good morning Mr. Chairman. I want to thank you for calling this hearing on an issue that unfortunately touches the lives of the American people on an annual basis: damage and economic loss from windstorms. Each year, lives are lost and billions upon billions of dollars are spent recovering from the destruction caused by tornadoes and hurricanes.

When the *National Windstorm Impact Reduction Act* was passed four years ago, the Federal Government recognized the need to proactively conduct research and development programs to save lives and reduce property damage caused by these horrific storms. I am looking forward to hearing from today's panel about both the successes of the National Windstorm Impact Reduction Program over the past four years, as well as improvements to the program that can be made moving forward.

Mr. Chairman, my home State of Georgia has a long and notorious history with tornadoes and windstorms, with several incidents in the past year and a half alone. In March of 2007, tornadoes struck the towns of Potterville, North Newton, and Americus, leaving nine people dead and tremendous damage in their wakes. In December in Ashburn, a truck driver was killed when a tornado blew his vehicle off the road.

This past March, Downtown Atlanta witnessed incredible damage to infrastructure when tornadoes ripped holes in the roof of the famed Georgia Dome during the 2008 SEC Men's Basketball Tournament. At the same time in my Northwest Georgia district, tornadoes struck Polk and Floyd Counties—causing significant economic loss and regrettably taking the lives of three of my constituents.

In addition to the lives lost, the United States sustains billions of dollars in economic damages each year due to tornadoes and hurricanes, and our vulnerability is only increasing. According to the Georgia Insurance Commissioner, insured losses across the State of Georgia in just the first five months of this year have surpassed $400 million.

Mr. Chairman, improved windstorm impact reduction measures have the potential to save lives and reduce losses associated with these storms. For instance, the Federal Government continues to invest in R&D activities that can increase warning time for tornadoes and other extreme weather events. While little can be done to protect structures from large tornadoes, researchers have made significant progress in designing buildings and retrofits to withstand high wind events.

Finding practical and effective applications for this research remains the biggest challenge that the National Windstorm Impact Program has today. This obstacle is unfortunately complicated by the number of stakeholders—federal agencies, State and local communities, and private organizations—that have a role in better preparing the Nation against windstorms. The R&D efforts in this program create ways for these stakeholders to collaborate in a productive and effective manner.

Mr. Chairman, I would like to thank the witnesses for coming to relate their expertise on the challenges, and hopefully the successes, of reducing windstorm impacts. This is a complex challenge with clear benefits that will require a great deal of cooperation, patience, and resolve to overcome, and I look forward to supporting these efforts.

Chairman WU. I thank the gentleman. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Ms. Richardson follows:]

PREPARED STATEMENT OF REPRESENTATIVE LAURA RICHARDSON

Thank you Chairman Wu for holding this very important hearing today, and our witnesses for their appearance. The purpose of today's hearing is to examine the activities of the National Windstorm Impact Reduction Program, and the role that R&D plays in reducing property loss and saving lives from windstorms.

Depending on the time of year, every region of the Nation has to confront a natural disaster. In California we have earthquakes and wildfires, so windstorm damage is an issue that those of us on the west coast are fortunate enough to avoid.

However, natural disasters of any kind can cause significant loss in life and property, thereby necessitating the need to prepare adequately.

In California we implemented strict building standards after the Northridge earthquake to combat the potential damage that natural disasters create, and this approach can serve as a model to states in the heartland and the South that have to deal with tornadoes and hurricanes respectively.

Now it should be noted that the National Windstorm Impact Reduction Program has not been funded at the authorized levels for several years now. This must change considering the fact that in 2007, 111 Americans died in tornadoes and thunderstorm winds, and tornadoes have already killed 119 people this year.

Likewise as more people move to coastal areas the threat of hurricanes obviously increases. Therefore as a matter of fiscal responsibility we owe it to the American people to increase R&D efforts that will mitigate the impact of windstorm damage. In 2004 and 2005 the economic impact of hurricane season totaled more than $160 billion dollars.

My personal work philosophy has always been to put the majority of my effort in on the front end in order to avoid subsequent damages on the back-end. This approach ought to be applied to matters pertaining to windstorm damage as well.

I look forward to a productive discussion, Mr. Chairman I yield back my time.

Chairman WU. I would now like to introduce our witnesses, and thank them for appearing before the Subcommittee this morning. Dr. Sharon Hayes, who is the Associate Director of the Office of Science and Technology Policy; Dr. Marc Levitan, who is the Director of the Louisiana State University Hurricane Center, where he is also a Professor of Civil and Environmental Engineering; Ms. Leslie Chapman-Henderson, who is the President of the Federal Alliance for Safe Homes, or FLASH, a not for profit organization devoted to mitigating the impact of storms on homes.

Dr. Timothy Reinhold, we understand, is delayed by the vagaries of either weather or the airlines, which are, well, no further comment on either one. And his statement, as earlier referred to, will be included in our record.

For our witnesses, spoken testimony is limited to five minutes each, after which the Members of the Committee will have five minutes to ask questions. Your written statements will be taken into the record in their entirety.

And Dr. Hays, we will begin with you. Please proceed.

STATEMENT OF DR. SHARON L. HAYS, ASSOCIATE DIRECTOR AND DEPUTY DIRECTOR FOR SCIENCE, WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. HAYS. Thank you, Mr. Chairman.

Chairman Wu, Ranking Member Gingrey, and Members of the Subcommittee, it is my pleasure to appear before you in this hearing on the National Windstorm Impact Reduction Program.

Every year in the U.S., windstorms are responsible for tremendous damage to property, and often, loss of life. Hurricane Katrina demonstrated how a severe hurricane can affect not just those in its path, but the entire country and its economy. Tornadoes and severe storms are also capable of tremendous destruction. As the Chairman mentioned, in 2008, the United States has been ravaged by a near record number of tornadoes that has pushed the death toll to a 10 year high. Thus, the topic of this hearing is both important and timely.

You asked me to address four questions. My written testimony provides more detail regarding several of your questions, including a summary of the activities of the National Windstorm Impact Reduction Program, which was the subject of your first question, so I will not repeat that summary here.

You also asked how the agencies involved in the Windstorm Impact Reduction Program receive input from the external community. This happens in a number of ways. The primary mechanism is through the National Research Council's Disasters Roundtable, which holds workshops on particular disaster-related topics that bring together experts from agencies, industry, academia, and non-governmental organizations. Several agency personnel sit on the Roundtable Steering Committee. Many others participate in the Roundtables themselves. A list of recent Roundtable topics can be found in Attachment 3 to my written testimony.

Another extremely important mechanism for getting non-government input on disaster related R&D occurs through agency-specific mechanisms. Here are several examples. One, NSF incorporates private sector researchers, particularly those in academia, on its peer review panels charged with helping make award selection decisions.

Two, through active participation and leadership in many standards development organizations, staff from NIST's Building and Fire Research Laboratory, which is the locus of NIST's windstorm-related research, contribute significant time and technical expertise to the process of developing national and international standards, and this brings them into direct contact with their peers in the private sector, and also helps translate the results of NIST research into practical applications.

Three, because some important disaster-related research can be done only in the aftermath of an event, FEMA assembles mitigation assessment teams, made up of government and private sector experts, to perform post-disaster assessments. These teams work closely together to understand the impacts of a disaster event on buildings—the results are of tremendous importance in defining new areas of research, as well as future building codes and standards. These examples reflect the different missions and operations of the agencies that perform disaster R&D. They provide multiple and complementary avenues for public/private communication.

You also asked for an update on efforts being taken to address current gaps in R&D identified in the Administration's Windstorm Impact Reduction Implementation Plan. Descriptions of specific agency activities and programs are included in my written testimony. And the Windstorm Working Group will also be providing Congress with an updated biannual report by later this year or early next year. That report will have more information on the working group's most recent activities.

Finally, you asked about a 2003 RAND report on Windstorms. The RAND Report represents a very thoughtful assessment of the role of R&D in helping make our nation more resilient to disasters. In fact, it was one of the guiding references used by the Subcommittee on Disaster Reduction, which is the interagency group that is charged with coordinating the Administration's disaster-related R&D. When developing their report on grand challenges for disaster—many of the issues raised in the RAND report are specifically identified in the grand challenges, which is an emphasis on mitigation strategies and technologies.

One of the RAND Report's implicit conclusions is the importance of considering disaster reduction R&D in an all hazards context, thus taking into account windstorm R&D alongside other disasters, such as floods, earthquakes, and wildfires. That all hazards context is a fundamental tenet of the Federal Government's current approach to coordination of disaster.

In closing, I would like to point out that in many instances, reducing the impacts of disasters ultimately requires actions beyond the purview of the Federal Government. The adoption of zoning laws, building codes, and other actions that can build resilience within communities are rightly vested in State and local authorities. Given this, I believe the most important roles of the Federal Government are in R&D that underpin technological innovations, such as improved prediction capabilities and better strengthen buildings and infrastructure, and in communicating the benefits of their adoption.

The Subcommittee on Disaster Reduction is an important mechanism for the Federal Government to perform these essential elements of developing a more disaster-resilient America.

Mr. Chairman, I am happy to answer any questions that you or other Members of the Subcommittee have at the appropriate time, and as I mentioned earlier, my written testimony contains much more detail, so I ask that it and its attachments be made part of the record.

[The prepared statement of Dr. Hays follows:]

PREPARED STATEMENT OF SHARON L. HAYS

I. Introduction

Chairman Wu, Ranking Member Gingrey, and Members of the Subcommittee, I am pleased to appear before you today to describe interagency activities related to the National Windstorm Impact Reduction Program (NWIRP). Wind hazards (hurricanes, tornadoes, severe windstorms) are among the most destructive and economically damaging hazards in the U.S. While other hazards strike irregularly, wind storms produce enormous damage in the U.S. year after year.

Reducing the likelihood and impact of natural and technological[1] disasters requires an understanding of science and technology, the transformation of research into disaster reduction programs and applications, and access to information from both public and private entities. In order to meet these challenges, the interagency Subcommittee on Disaster Reduction (SDR) of the National Science and Technology Council (NSTC) was chartered in 1988. The SDR provides a unique federal forum for information sharing, development of collaborative opportunities, formulation of science- and technology-based guidance for policy-makers, and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks.

In many instances, reducing the impacts of disasters ultimately requires actions beyond the purview of the Federal Government. The adoption of zoning laws, building codes, and other actions that can build resilience within communities are rightly vested in State and local authorities. In these instances, the most important roles of the Federal Government are in research and development (R&D) that underpin technological innovations and in communicating the benefit of such actions. The SDR, and its working groups, are important mechanisms for the Federal Government to perform these essential elements of developing a more disaster-resilient America.

The overarching philosophy of the SDR is to examine R&D needs for specific types of disasters within an all-hazards view. Accordingly, basic research on the resilience of structures to wind are coordinated with similar studies related to flooding and storm surge because all three phenomena commonly occur together in hurricanes or severe storms. Likewise, the end-to-end aspects of hazards and disasters are consid-

[1] The term "technological disasters" refers to accidental releases of hazardous substances, such as an oil or toxic chemical spill.

ered as a whole; basic research on natural processes that cause disasters is linked to risk assessment, preparedness, and the economic and social impact of disasters. The primary goal of hazard research is to reduce loss of life and property and therefore hazards must be viewed holistically.

Specifically, the SDR facilitates U.S. Government and private/academic activities to reduce vulnerability to natural and technological hazards through:

- Coordinating national research goals and activities for federal research related to natural and technological hazards and disasters;
- Identifying and coordinating opportunities for the U.S. Government to coordinate and collaborate with State, local, and foreign governments, international organizations and private/academic/industry groups;
- Facilitating the identification and assessment of risks;
- Providing information to the President and Congress to summarize relevant resources and work within SDR agencies;
- Providing information to the Administration and Congress in response to current disaster situations;
- Working with public and private sector policy development bodies;
- Promoting disaster reduction practices;
- Facilitating the exploitation of dual-use systems and fusion of classified and unclassified data streams and research for disaster reduction applications.

The membership and reach of the SDR across the Federal Government is expansive and includes 25 government organizations:

- Department of Defense
  - Networks and Information Integration (NII)
  - United States Army Corps of Engineers
- Department of Energy
- Department of Health and Human Services
  - Centers for Disease Control and Prevention
  - National Institutes of Health
  - United States Public Health Services Commissioned Corps
- Department of Homeland Security
  - Federal Emergency Management Agency
  - United States Coast Guard
- Department of Housing and Urban Development
- Department of State
  - United States Agency for International Development
- Department of the Interior
  - United States Geological Survey
  - The Bureau of Land Management
- Department of Transportation
- Environmental Protection Agency
- Federal Energy Regulatory Commission
- National Aeronautics and Space Administration
- National Geospatial-Intelligence Agency
- National Guard Bureau
- Department of Commerce
  - National Institute of Standards and Technology
  - National Oceanic and Atmospheric Administration
- National Reconnaissance Office
- National Science Foundation
- United States Department of Agriculture
  - United States Forest Service

With such a long list of participating agencies, and an active membership base, the SDR has been a model for interagency coordination. Thus, the SDR was a logical choice to act as the NSTC oversight body for interagency activities on Windstorm Impact Reduction.

II. Actions to date

In October 2004, Congress passed the *National Windstorm Impact Reduction Act,* which originated in the House Science Committee. The bill called for the establishment of the National Windstorm Impact Reduction Program (NWIRP), with the objective of achieving "major measurable reductions in losses of life and property from windstorms." The legislation tasked OSTP with creating a NSTC Interagency Working Group (IWG) on Windstorm Impact Reduction. In January 2005 the NWIRP IWG was convened by the NSTC SDR. The legislation mandated participation by NOAA, NSF, NIST, and FEMA. While those agencies have taken the most active role in the IWG, other federal entities, such as the Federal Highway Administration, Department of Housing and Urban Development, National Aeronautics and Space Administration and U.S. Army Corps of Engineers, have also participated in the program.

The legislation required that an implementation plan for achieving the objectives of the Program be submitted to Congress. The *Windstorm Impact Reduction Implementation Plan* was submitted to Congress on April 5, 2006 (Attachment 1). The plan outlines how NSTC, in accordance with its responsibility to coordinate science and technology across federal agencies, can establish a framework to address multiagency science and technology issues related to windstorm mitigation. Specifically, the plan focuses on identifying research needs that will be an important component of long-term efforts to reduce the impacts of wind hazards. The plan continues to serve as a guide for the IWG as it works to improve coordination of existing wind-related research, and seeks to fill research gaps in understanding, predicting, and forecasting windstorm hazards.

During the formulation of the plan, the IWG reached well beyond the participating federal agencies to State, county, and city governments, universities, and non-government organizations such as the American Association of Wind Engineers (AAWE), the American Society of Civil Engineers (ASCE), and the Institute for Building and Home Safety (IBHS) for input. The IWG met several times during the creation of the implementation plan and several drafts were circulated throughout the participating agencies. The end product is a useful and comprehensive document.

The legislation also required the development of biennial updates to the implementation plan. The first of these updates was transmitted to Congress on November 20, 2007 (Attachment 2). The biennial update covers Fiscal Years 2005 and 2006 and provides a summary of wind hazard research activities, and progress toward agency goals in each of the NWIRP agencies aimed at understanding, predicting and forecasting wind hazards, assessing and reducing impacts of wind hazards, and promoting preparedness and enhancing community resilience. It also identifies areas of research, compiled by the IWG, that address important national wind hazard problems in the future. The biennial update serves as an excellent resource for understanding each NWIRP agency's contribution to the program. As stated in a June 23, 2008 letter from Dr. John Marburger III to Chairman Gordon, the next biennial report will be submitted to Congress in fall 2008 or spring 2009 (Attachment 3).

III. Grand Challenges for Disaster Reduction

As noted above, the IWG on Windstorm Impact Reduction operates under the auspices of the SDR. Given its close link to the SDR, the NWIRP follows the same philosophical underpinnings established in the SDR's February 2008 report *Grand Challenges for Disaster Reduction* (Attachment 4). These challenges are as follows:

Grand Challenge #1—Provide hazard and disaster information where and when it is needed

Grand Challenge #2—Understand the natural processes that produce hazards

Grand Challenge #3—Develop hazard mitigation strategies and technologies

Grand Challenge #4—Recognize and reduce vulnerability of interdependent critical infrastructure

Grand Challenge #5—Assess disaster resilience using standard methods

Grand Challenge #6—Promote risk-wise behavior

The *Grand Challenges for Disaster Reduction* report was released on February 1, 2008 and is a ten-year strategy that is focused on the application of science and technology to enhance community resilience to disasters and create a more disaster-resilient nation.

To implement this ten-year strategy, the 25 federal departments and agencies of the SDR worked together to identify specific actions that they, in collaboration with State and local governments, as well as individuals and institutions in the private sector, must take in order to meet the Grand Challenges. The resulting framework of prioritized federal science and technology actions, which is compiled in 14 hazard-specific implementation plans, can help increase the Nation's disaster resilience by guiding future investments.

Of the 14 hazard-specific implementation plans, three are directly linked to the IWG on Windstorm Impact Reduction; Tornadoes (Attachment 5), Hurricanes (Attachment 6) and Winter Storms (Attachment 7). The IWG helped guide the creation of these plans.

IV. Overview of agency work in the area of wind hazards

The *Windstorm Impact Reduction Implementation Plan* described four major themes for wind hazard research:

- Understanding, Predicting, and Forecasting
- Assessing Impacts
- Reducing Impacts
- Preparedness and Enhancing Community Resilience

Agency activities in these four areas are performed in the context of each agency's mission and consistent with their research practices. These activities are focused in several areas: continued improvement in windstorm prediction; local, State, regional and federal coordinated research response capabilities following wind hazard events, including field validation and data collection capabilities for buildings, critical infrastructure and essential facilities; windstorm damage and loss estimation modeling tools; and standards and technologies that will enable cost-effective, state-of-the-art windstorm-resistant provisions to be adopted as part of State and local building codes. The following discussion outlines ongoing efforts to address the need for improvement in these areas, organized by agency.

National Science Foundation

The National Science Foundation (NSF) supports unsolicited research proposals related to NWIRP topics ranging from atmospheric sciences research that is concerned with the physics of hurricane, tornado, and thunderstorm formation, to engineering programs focused on improving the performance of structures against wind loads, to social science programs devoted to societal preparedness and response to natural disasters. Although these proposals are selected through the peer review process under programs intended to advance research in myriad areas and not just hurricanes and winds, the NSF portfolio of projects have collectively made important progress in each of four focus areas defined above.

For example, significant progress in documenting and analyzing the damage caused to civil infrastructure by wind and hurricane driven storm surge was made by NSF-supported investigators as a result of awards made immediately after Hurricanes Katrina and Rita. Social science topics under continued investigation include evaluating preferences for rebuilding plans post-Katrina, assessing public health impacts of disasters, decision-making in displaced populations, and examining factors associated with compliance to Katrina mandatory hurricane evacuation orders in seven coastal Louisiana parishes.

NSF funds research that often directly leads to changes in building code revisions through development of new materials and/or design methodologies. New awards directly related to design of wind-resistant structures include five that have been made through the Hazard Mitigation and Structural Engineering Program in the Engineering Directorate during the past 12 months. One of these, "Hurricane Wind Simulation and Testing to Develop Damage Mitigation Techniques,"[2] will develop a cost-effective, light, strong, ductile, and non-intrusive roof-to-wall connection system using high performance fiber composite materials to improve hurricane resiliency of residential buildings. A second one, "Performance Based Wind Engineering: Interaction of Hurricanes with Residential Structures,"[3] is expected to improve design methods for wood frame buildings through the use of the performance-based

[2] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0727871*
[3] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0800023*

design approach. Research results will be disseminated through the ASCE/SEI committees in which the Principal Investigator is involved.

Understanding, Predicting and Forecasting

Over the past two years, research in atmospheric sciences has yielded a better understanding of atmospheric dynamics of straight-line winds and improved knowledge of the fundamental physics that control hurricane intensity, wave dynamics during hurricanes, and the impact of externally and internally modulated convection on tropical cyclone evolution.[4] Understanding the hazard risk associated with extreme hurricane events is also being studied. Detecting synoptic-scale precursors of tornado outbreaks[5] is the objective of one investigation. Another project is studying tornadic storms with Doppler Polarimetric Radar.[6]

Assessing the impacts of wind hazards

Shortly after Hurricane Katrina struck the Gulf States, 29 small grants were awarded for reconnaissance studies aimed at documenting their effects and preserving highly perishable data. Two of these studies, on the performance of the levee system, were expanded in scope to include engineering analyses of failed sections of the levees and proposed repair and replacement strategies. Development of instrumentation for the observational studies of the effects of atmospheric winds on structures near the ground was also undertaken. Another of these projects investigated large coastal bridge performance in a hurricane environment. Collection of perishable data on wood-frame residential structures in the wake of Hurricane Katrina was also undertaken. Studies were conducted to better understand the response of typical bridges to hurricanes and to assessing risk for long-span bridges. The determination of storm surge effects on levees and the simulation of non-linear water waves during hurricanes were the subjects of other investigations. In order to better understand the impacts of hurricane disasters, construction material requirements for rebuilding New Orleans are being investigated and documented. Improving glass performance during wind storms and the modeling response of tall buildings to straight line winds are important for understanding the impacts to wind hazards.

Social science topics under investigation include evaluating preferences for rebuilding plans post-Katrina, assessing public health impacts of disasters, and decision-making in displaced populations. In particular, one project is examining factors associated with compliance to Katrina mandatory hurricane evacuation orders in seven coastal Louisiana parishes.

Reducing Impacts of Wind Hazards

Resistance of existing wood roof structures and retrofit schemes is currently being studied to better understand how best to construct more resistant structures in the future. This type of damage accounts for a significant portion of the damage caused by hurricanes and straight line winds each year. In addition, a better understanding of the impact of hazard events on soils, infrastructure, and the submerged environment is required. A project entitled "The Effect of Katrina on Submerged Geotechnical Systems—Underwater Evaluation of Sediment-Structure-Storm Interaction" will provide important data on these important parts of the urban infrastructure. Another project that is vital to the energy supply is focusing on assessment of damage to underground tanks in New Orleans in the aftermath of Hurricane Katrina. Electric Utility Damage from Hurricane Katrina is also under investigation.

Preparedness and Enhancing Community Resilience

Instructional materials for K–12 students are being developed to enhance preparedness among children. Also, information technologies are being developed to assist individuals in adapting to evacuation. Social networks are being studied to understand the role they might play in early warning strategies and subsequent compliance. Improving hurricane intensity forecasting is important to increase societal compliance and evacuation plans and orders, but the public must also be educated to understand risk and appropriate behavior to ensure their safety. Two studies are underway to better understand and improve evacuation procedures. Two projects have been funded for analyzing multi-organizational networks and their roles in hazard mitigation. Ten projects are underway that are investigating various tools

[4] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0514199*
[5] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0527934*
[6] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0532107*

that might be useful for building community resilience to wind hazards. One of these projects is examining how preferences for rebuilding plans are being made after Hurricane Katrina.[7] Another one is studying "The Parallel Strengths and Weaknesses of the Civil Society and the State: The Example of Katrina Survivors."[8] "Cyberinfrastructure Preparedness for Emergency Response and Relief: Learning the lessons from Hurricane Katrina" is the focus of another investigation.[9]

The majority of NSF support for wind hazard R&D activities is in response to unsolicited proposals, although some support is provided through the National Center for Atmospheric Research (NCAR) and the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA). NSF is also sponsoring a joint solicitation with NOAA on Communicating Hurricane Information. NSF estimates that $6.7 million will be spent on wind hazard R&D in FY 2008.

National Oceanic and Atmospheric Administration

NOAA activities and progress during the past two years can be divided into six categories: 1) development of plans; 2) provision of data of use for wind hazard reduction; 3) development of decision support tools and analyses of relevance to wind hazards; 4) understanding and predicting weather conditions producing wind damage; 5) creation of new facilities for improving our knowledge and prediction of wind hazards; and 6) education and outreach.

Development of plans

NIST and NOAA jointly developed a cooperative plan on Hazard-Resilient Communities, and are moving forward with the storm surge component of that plan. NOAA is represented on the U.S.–Japan Panel on Wind and Seismic Effects. This panel encourages exchange of information between the two countries and is completing a joint project on bridge stay flutter. It is also proposing a workshop to exchange information between wind structural engineers and meteorologists who work on wind issues to determine the needs of and opportunities presented by the two communities working closely together. The workshop is anticipated to occur within the next year.

Providing data of use for wind hazard reduction

During FY 2004, several extreme turbulence (ET) probes were developed and successfully tested in actual hurricanes. These probes hold promise for very high spatial and temporal resolution measurements of winds on the immediate exterior of structures. In cooperation with NOAA, the Florida and South Carolina Sea Grant deployed portable towers measuring winds during Hurricanes Charley, Frances, Ivan, Katrina, and Rita. These data are useful for "nowcasts" of the winds and to duplicate wind tunnel measurements. The Shared Mobile Atmospheric Research and Teaching Radars (SMART–R), the result of a cooperative effort between the University of Oklahoma and NOAA, have been used in hurricane landfall deployments, and have been upgraded to deliver their data directly to forecast offices in real time. The stepped frequency microwave radiometer is now deployed on both research and operation aircraft for much improved surface wind and vertical wind profiles over water within hurricanes and they are now used in NOAA's operational hurricane model and for real-time hurricane intensity analysis.

Decision support tools and analysis for wind hazards

NOAA has been working with the State of Florida on a Public Hurricane Loss Projection Model to develop wind-dependent vulnerability functions for building retrofit guidance. The NOAA hurricane wind (H*WIND) analysis was used to validate this model. A stochastic model is being used to simulate 55,000 years of hurricane tracks for a wind demonstration project, conducted with NIST, to test wind and storm surge risk maps in a few selected coastal areas. The U.S. Army Corps of Engineers and NOAA completed a post-Hurricane Katrina, Charley, Frances, Ivan, and Jeanne 1-km resolution wind field analysis using the H*WIND product and data that were not available in real time. NOAA's National Hurricane Center introduced its new experimental wind-speed probability forecast in time for the 2006 hurricane season to map out several predicted wind-speed thresholds.

[7] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0554987*
[8] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0555113*
[9] *http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0638561*

Understanding and predicting weather conditions producing wind damage

NOAA continues to gather field data on hurricane inner core dynamics to better understand intensity changes. During the past two hurricane seasons, NOAA, with the Office of Naval Research, has been measuring the heat and momentum exchange between the atmosphere and ocean within hurricanes to better parameterize this exchange in hurricane prediction models. Preliminary testing of these new parameterizations in NOAA's operational hurricane model has improved hurricane intensity predictions. NOAA tested a new hurricane model during the 2006 hurricane season for operational application next season. It is coupled with an ocean model and has a nested and movable grid.

The President's 2009 Budget includes nearly $20 million for hurricane-related increases across NOAA, including modeling improvements on forecasts and storm surge and research into ocean vector winds and coastal inundation. The 2009 Budget also includes an increase of $242 million for the GOES–R satellite system, which is a critical component of NOAA's hurricane monitoring.

Creating new facilities for improving our knowledge and prediction of wind hazards

The new National Weather Center in Norman, Oklahoma opened its doors during the summer of 2006. It consists of the South Research Campus of the University of Oklahoma, the NOAA Norman forecast office, the Storm Prediction Center, and the National Severe Storms Laboratory. This facility also features the Hazardous Weather Testbed, which performs research and development to improve prediction of hazardous winds.

Education and outreach

- NOAA's Louisiana Sea Grant program has developed fact sheets that include information on building codes, where and how to rebuild, and how to determine if a contractor is following State and federal regulations. It has been distributed to parishes and is available on the Internet. The program has also sponsored seminars on storm preparedness and has provided information on building codes and zoning practices.
- NOAA's Texas Sea Grant Program (Texas A&M) has been evaluating the Texas Mitigation Plan, which includes construction codes.
- The North Carolina Sea Grant (North Carolina State in collaboration with Oregon State) developed a break-away wall design for 125-mph winds and 1.5-ft waves, which has been adopted by the American Society of Civil Engineers.
- The South Carolina Sea Grant (Clemson) has developed low-cost methods for reducing storm damage, including strengthening roofs and shutters which have been adopted by a Sun City developer.
- There is now a "hazards house" in Charleston, SC, that helps educate the public on hazard-resilient building and retrofitting techniques, including those that mitigate wind effects.
- NOAA has prepared material for a documentary on how to stay safe in high winds, including how to improve housing construction to resist damage and the appropriate design for safe rooms. The documentary will be featured on the Discovery Channel.
- NOAA held its first Weather Partners open house in Norman, OK, for approximately 1000 visitors. Wind risk to structures was a prominent theme for discussion.
- NOAA organized a training session at the National Hurricane Conference on hurricanes and public health. During the session, a representative from the Institute of Building and Home Safety delivered a presentation on the resilience of public health facilities against structural hazards. Key structural components included window strength, exterior cladding, roof edging, and vulnerability of roof type and roof mountings. The participants then critically evaluated a simulated hurricane scenario.

National Institute for Standards and Technology

NIST research over the past two years has focused on gaining an understanding of wind hazards to the built environment and developing predictive technologies and mitigation strategies to enhance disaster resilience to wind hazards.

Extreme Wind Databases

To facilitate use of Automated Surface Observing Station (ASOS) wind data for structural engineering purposes, NIST developed procedures and software for (a) extraction of peak gust wind data from archived ASOS weather reports, (b) extraction of thunderstorm observations from archived weather reports, (c) classification of wind data as thunderstorm or non-thunderstorm to enable separate statistical analyses of these distinct types of winds, and (d) construction of data sets separated by specified minimum time intervals to ensure statistical independence. Estimates showed that, at these stations, thunderstorm wind speeds dominate the extreme wind climate to the extent that non-thunderstorm wind speeds can be disregarded in the analysis. Using such records it is possible to obtain realistic probabilistic descriptions of the wind climate at stations where both types of wind occur. The software, data, and literature are available at *www.nist.gov/wind.*

Advanced Computational Tools for Determining Realistic Wind Loads in the Built Environment

NIST has developed software for analyzing wind effects on rigid, gable-roofed buildings, and flexible high-rise buildings using the database-assisted design methodology. Database-Assisted Design (DAD) is a unified framework for analysis and design of buildings for wind loads that makes direct use of pressure-time histories measured at a large number of pressure taps on wind tunnel models. Local climatological information can be used in conjunction with the measured pressures to obtain estimates of peak wind effects with specified return periods for use in structural design. DAD offers more accurate estimation of peak wind effects than simplified procedures that are now used, which paves the way for more risk-consistent designs. The software, data, and literature are available at *www.nist.gov/wind.*

Methodologies for Predicting Ultimate Structural Capacities and Estimating Safety Margins

The design of many low-rise metal buildings in the U.S. is based on the ASCE 7–93 Standard and the use of Allowable Stress Design (ASD). NIST used the non-linear database-assisted design technique to assess the degree of safety of a typical low-rise portal frame industrial structure designed in accordance with ASCE 7–93 and ASD as compared to the provisions of the ASCE 7–02 Standard. NIST has found that the frame being considered satisfies all ASCE 7–02 requirements with respect to wind loading but that its safety level is relatively low and could be improved substantially at very low cost.

Assessing the Performance of Structures in Wind Disasters

NOAA's National Weather Service implemented the enhanced Fujita Tornado Intensity Scale on an operational basis in February 2007. The enhanced Fujita scale is based upon observations by a NIST researcher as part of a reconnaissance team deployed following the 1997 Jarrell, TX tornado and subsequent technical work performed by Texas Tech University with funding and technical oversight by NIST. The more realistic wind speeds associated with the enhanced scale will allow the use of routine standard provisions for the safe design of buildings under most tornadoes occurring in the U.S.

After Hurricane Katrina and Hurricane Rita, NIST assembled a team of experts to conduct a reconnaissance of the status of buildings, physical infrastructure, and residential structures in the New Orleans area, coastal Mississippi, and Southeast Texas. NIST documented its findings on the environmental conditions (e.g., wind speeds, storm surge elevations, and flooding) and on the performance of structures in the study areas in its final report issued in June 2006. The report includes 23 recommendations in three groups: 1) immediate impact on practice for rebuilding, 2) standards, codes, and practices, and 3) further study of specific structures or research and development.

Technical Basis for Improved Codes and Standards

Estimates of the World Trade Center (WTC) towers' response to wind by two North American wind engineering laboratories differed from each other by almost 50 percent. A NIST investigation indicated that those differences reflected discrepancies between the respective estimates of the wind speeds and the respective modeling of directional interaction between wind speeds and aerodynamic/dynamic response of the building. NIST analyzed the role of risk-consistent probabilistic definitions of peak wind effects in developing safety margins for inclusion in codes and standards.

U.S.–Japan Panel on Wind and Seismic Effects

NIST chairs the U.S.–Japan Joint Panel on Wind and Seismic Effects and NIST staff actively participates in the Panel and its wind engineering task committee. The Panel provides an effective mechanism for the exchange of technical data and information, the exchange of researchers, and the coordination of joint research on topics of mutual interest to the U.S. and Japan.

Wind-related Storm Surge

Hurricane Katrina demonstrated that (1) hurricane storm surge can substantially exceed heights defined by existing flood hazard maps, and (2) there is a lack of a methodology for assessing the risk associated with different joint hurricane wind speed/surge height events that can be used for establishing risk-consistent design criteria for structures in coastal regions exposed to the combined effects of hurricane wind and storm surge. Such methodology must take into consideration the effects of local topography and bathymetry, on which storm surge at any specific location is highly dependent, as well as hurricane parameters such as track, forward speed, wind speed, and central pressure. NIST/BFRL is working in collaboration with NOAA's National Weather Service, Office of Atmospheric Research and National Hurricane Center, and the University of Florida, to develop this methodology. NIST and NOAA have developed the basic methodology using the Florida Public Hurricane Loss Model and demonstrated the methodology for a small number of stations in the Tampa Bay area. The objective of this work is to develop this methodology such that it can be used to estimate the joint probability for wind and storm surge events (including wave action) along the U.S. coastline and provide the technical basis for improving the hazard criteria used for application of flood resistant design provisions.

Federal Emergency Management Agency

FEMA supports a variety of NWIRP-related activities including risk assessment, windstorm-related data collection and analysis, mitigation promotion and public outreach, and hurricane program coordination.

Risk Assessment

FEMA developed HAZUS–MH, a risk assessment program that analyzes potential losses from floods, hurricane winds and earthquakes. HAZUS–MH combines current scientific and engineering knowledge with the latest GIS technology to produce hazard-related damage estimates before or after a hazard event. The current version of the software program—HAZUS–MH MR2—allows communities to access a risk assessment tool that can serve as a basis for mitigation planning and policy development, emergency preparedness, and emergency response and recovery exercises.

Data Collection and Analysis

After major natural hazard events, a Mitigation Assessment Team—or MAT—study may be conducted to perform engineering analyses, assesses damage, determine the causes of structural failures and successes, and prepare recommendations regarding construction codes and best practices. Communities and construction professionals, in turn, use MAT information and recommendations to plan for, and reduce damages from, future events. *A telling MAT conclusion following Hurricane Katrina: buildings that experienced substantial structural damage from Katrina typically were built before building design and construction professionals adequately considered wind effects.*

Promoting Mitigation—Education and Public Outreach

To educate communities about mitigation and the steps they can take to reduce their vulnerabilities to natural hazard events, FEMA and the MAT continue to develop first-of-its-kind construction advice guidance. Widely disseminated, FEMA's mitigation guidance provides Gulf coast residents with engineering recommendations and foundation solutions for rebuilding; many of which are being incorporated into local reconstruction efforts. Additionally, the MAT publication *FEMA 550 Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations* provides homeowners, builders, and design professionals with prescriptive, pre-engineered foundation solutions, cost information, and guidance on choosing and building disaster-resistant foundations.

Hurricane Program Coordination

FEMA and NOAA work together to improve the Nation's hurricane evacuation planning. NOAA research produces improved hurricane intensity predictions which, in turn, help FEMA and emergency managers across all governmental levels with critical planning, evacuation, response, and recovery decisions. Since 2004, despite resource and funding limitations, the NWIRP partnership has collaborated to: enhance knowledge and information on severe winds; investigate the wind resistance of buildings and structures; develop improved tools for assessing wind hazard losses; improve public awareness of wind hazards and related mitigation; and enhance wind hazard-related evacuation planning and guidance.

While not specifically identified as NWIRP funding, FEMA's FY 2004–2008 budgets have funding in the Mitigation Directorate, Risk Reduction Division that has been characterized as meeting the basic goals of the NWIRP. The funding level for FY 2004–FY 2008 was between $200–$350K per year for a total of approximately $1.5 million. In FY 2009 FEMA anticipates $200–$250K of funding. Specific areas of activity include:

- FEMA support for wind-resistant national Model Building Codes and Consensus Standards;
- FEMA support for the development of national Wind Shelter guidance and standards; and ongoing support for hurricane evacuation studies

Federal Highway Administration

Understanding, Predicting and Forecasting Wind Hazards

The FHWA Office of Infrastructure R&D continuously monitors winds at the sites of three major long-span, cable-supported bridges to establish and characterize site-specific wind conditions and the responses of the bridges. All sites are relatively near the coastline with one in Louisiana, another in Delaware, and the third in Maine. A new site will be added monitoring the Bill Emerson Bridge at Cape Girardeau, Missouri. The engineering data collected at these sites provides valuable input into design of new structures.

Assessing the Impact of Wind Hazards

The FHWA Office of Infrastructure R&D has continuously monitored the wind environment and detailed response of three major long-span, cable-supported bridge structures to evaluate their wind performance and wind resistance with one more site being added in 2008. The Computational Fluid Dynamics (CFD) model UABRIM is being enhanced by implementation of unstructured and adaptive grids for use in simulating the interaction between wind and structures such as large bridges. Tests have been completed in the FHWA's small wind tunnel at the Turner Fairbank Highway Research Center using evolving Particle Image Velocimetry (PIV) technology to study wind flow fields around and compute wind forces on several representative bridge deck sections. This small wind tunnel has been automated for more efficient operation.

The FHWA Office of Operations continued activities under the Road Weather Management Program, which seeks to develop and promote effective tools for observing and predicting the impacts of weather on the roads, and to alleviate these weather impacts. As part of the program, the Clarus Initiative has continued to conduct activities to develop and demonstrate an integrated surface transportation weather observing, forecasting and data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System. The Initiative Coordinating Committee (ICC) held its annual meeting in August 2008. Phase 3 of the Clarus Regional Demonstration will be initiated shortly show-casing how road and weather observations from the Clarus System can be used to develop and deploy more advanced road weather management solutions for transportation operations.

Reducing the Impact of Wind Hazards

The FHWA Office of Infrastructure R&D continues to conduct research to prepare a synthesis report on Wind Load Criteria for Cable Supported Structures. Complementary research has also been initiated to prepare a synthesis report on User Comfort and Serviceability Criteria for Wind Loading. Research has continued on the study of wind- and wind/rain-induced vibration of bridge stay cables a major issue for bridge owners. A second version of the guidelines document has been developed for the aerodynamic design of bridge stay cables.

Preparedness and Enhancing Community Resilience

The FHWA Office of Infrastructure R&D, together with the Missouri Department of Transportation, organized and held the 2nd National Workshop on Wind-Induced Vibration of Cable-Stayed Bridges in April 2006. This workshop served to disseminate the latest information on the mitigation of wind-induced vibrations to State bridge engineers and design consultants. FHWA has been participating in international conferences such as the 7th International Symposium on Cable Dynamics in Vienna Austria in 2007, and the 7th Colloquium on Bluff Body Aerodynamic and Application in 2008 in Milan, Italy to transfer to research knowledge. Further, FHWA continues to assist State DOTs to solve wind and wind induced issues as they arise.

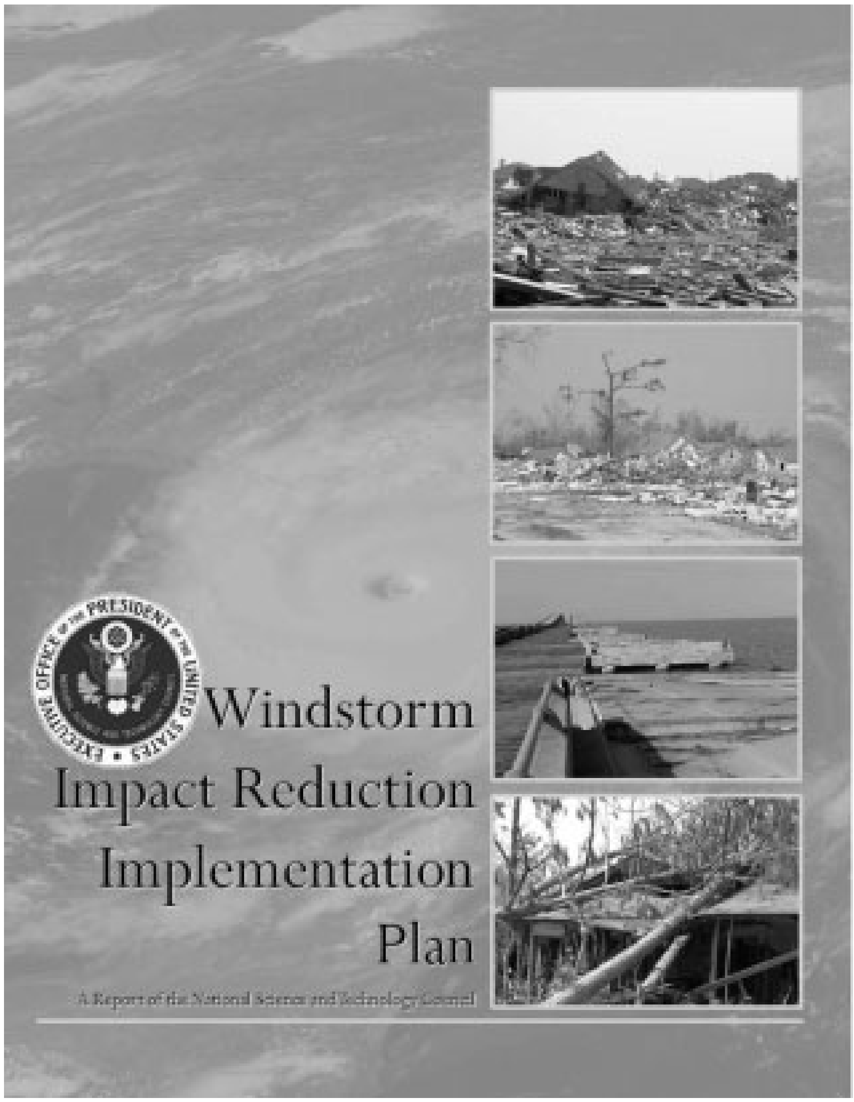
V. Conclusion

Measurably reducing losses of life and property from windstorms, including hurricanes, tornadoes, and seasonal storms, remains a high priority. As pointed out by the variety of reports available on the subject, such reduction will be predicated on improving the ability to predict the occurrence, location, and magnitude of windstorms with sufficient accuracy to allow the public and emergency managers to take appropriate measures and to increase the resiliency of our communities by constructing wind resistant buildings, highways, and other key portions of infrastructure. The federal agencies support robust research programs in these areas, and have made significant progress in making the results of this research more widely available. The benefits of this improved understanding will not be fully realized, however, until it is incorporated more completely into actions at the State and local level, both through building codes, design standards, and construction practices.

The importance of developing resilient communities will likely be further underscored as the Earth's changing climate will likely make historic trends in storm frequency and intensity a less reliable predictor of future conditions. Adaptation to a warming climate and accompanying changes in the nature of wind-related hazards will create a greater impetus for federal efforts to understand and predict wind hazards on a time scale longer than the typical weather forecasts available today, so that knowledge can inform the construction of buildings, bridges, and other components of the physical infrastructure intended to function safely for the next 30 to 50 years.

The NWIRP partnership must keep working with other federal agencies, State and local governments, academia, and the private sector to help our nation's communities understand and plan for their risks and take steps to reduce them and must find ways to address critical NWIRP issues in an environment of limited resources.

Attachment 1



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1. EXECUTIVE SUMMARY

The tragedy caused by Hurricanes Katrina and Rita in August and September 2005, the unprecedented hurricane season of 2004 in which five hurricanes made landfall in Florida, and the May 1999 outbreak of damaging tornados in Oklahoma underscore the significant and growing risks to our society due to wind hazards. Public Law 108-360, known as the National Windstorm Reduction Act of 2004, was signed into law by President Bush to reduce the risk wind hazards pose to life and property. The law increased national attention on wind hazard reduction efforts, which will require significantly improved cooperation and coordination between Federal agencies, improved coordination with states and local governments and increased, focused Federal investment to reduce wind hazards.

Although there are current and ongoing activities related to, or focused on, wind hazards it is clear that these efforts are more often merely small parts of larger efforts and are not coordinated among the agencies. For example, the National Oceanic and Atmospheric Administration (NOAA) makes weather predictions regarding several physical parameters of which wind is only one part; the National Institute of Standards and Technology (NIST) studies structural hazards ranging from earthquakes to fires, and winds are only one component; and the Federal Emergency Management Agency (FEMA) conducts evacuation planning studies, promotes wind preparedness activities, and advocates enhancements to the nation's model building codes as part of multi-hazard programs.

Each agency's effort toward wind hazard reduction is detailed in Appendix C. There appears to be virtually no duplication of effort among the agencies but there are gaps in knowledge, implementation and coordination.

In accordance with the legislation, a coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, will improve the understanding of windstorms and their impact, and develop and encourage implementation of cost-effective mitigation measures to reduce those impacts while promoting community resilience. We recommend a coordinated, comprehensive multi-agency, multi-disciplinary group be established as a working group of the National Science and Technology Council's Committee on Environment and Natural Resources Subcommittee on Disaster Reduction to reduce the impact of wind hazards by facilitating better communication among agencies, effectively allocating collective resources and operating within a common framework. This working group shall meet at least quarterly, report to the Subcommittee on Disaster Reduction annually and work with state, local officials and non-government organizations as appropriate. All Federal agencies contributing to this document shall be members of the working group and the chair of the working group will rotate between NIST, NSF, NOAA and FEMA with each Agency serving a two year term as chair.

A coordinated portfolio that builds on current efforts in research and mitigation activities should be developed including:

- Assessing individual and community capability to respond to wind events, including vulnerability analyses, risk perception, risk communication, risk management, communication of wind warnings and public response, evacuation capability, and public knowledge of appropriate protective actions for wind events, especially among vulnerable populations

- Evaluating the response of the built environment and critical infrastructure to wind events by investigating aerodynamic response, load path, ultimate capacity and the performance of the building envelope
- Assessing the impact of wind and windborne debris or wind and water/ice/snow
- Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
- Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
- Developing new technologies and ground, airborne and satellite based observing systems to improve knowledge and understanding of windstorms and the wind variability within those storms
- Measuring the response of bridges and other highway structures to wind events, including stability, serviceability and functionality leading up to and through extreme events
- Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services

There could be improvements in and enhancement of:
- Windstorm prediction
- Local, state, regional and federal coordinated response capabilities following wind hazard events, including field validation and data collection capabilities for buildings, critical infrastructure and essential facilities
- Windstorm damage and loss estimation modeling tools
- Standards and technologies that will enable cost-effective, state-of-the-art windstorm-resistant provisions to be adopted as part of state and local building codes

These improvements and enhancements would enable more effective:
- Local, state, regional and federal coordination in response to wind hazard events
- Evacuations through more informed planning and annual drills
- Local and regional preparedness through public-private partnerships fostering outreach and technology transfer programs
- Windstorm impact reduction practices through training and outreach programs that enhance state and local capabilities

2. PURPOSE AND SCOPE

Public Law 108-360, Title II, known as the National Windstorm Impact Reduction Act of 2004, was signed into law by President Bush on October 25, 2004. This law seeks to measurably reduce the loss of life and property from windstorms. The law states that,

No later than 90 days after the date of enactment of this Act, the Director of the President's Office of Science and Technology Policy shall establish an Interagency Working Group consisting of representatives of the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the National Institute of Standards and Technology (NIST), the Federal Emergency Management Agency (FEMA), and other Federal agencies as appropriate. The Interagency Working Group will be responsible for the planning, management, and coordination of the Program, including budget coordination.

- *NIST shall support research and development to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines.*
- *NSF shall support research in engineering and the atmospheric sciences to improve the understanding of the behavior of windstorms and their impact on buildings, structures and lifelines.*
- *NOAA shall support atmospheric sciences research to improve the understanding of the behavior of windstorms and their impact on buildings, structures, and lifelines.*
- *FEMA shall support the development of risk assessment tools and the effective mitigation techniques, windstorm-related data collection and analysis, public outreach, information dissemination, and implementation of mitigation measures consistent with the Agency's all-hazards approach.*

The Act further stipulates that not later than one year after the date of enactment of this title, the Interagency Working Group shall develop and transmit to Congress an implementation plan for achieving the objectives of this Program. This document is that plan.

3. INTRODUCTION

3.1 COSTS OF STRUCTURAL WIND DAMAGE

The 2005 hurricane season brought storms that wreaked havoc, causing large-scale damage from wind and water across many states. It was the most costly hurricane season in U.S. history. Hurricanes Katrina, Rita and Wilma demonstrated in dramatic fashion how costly these events can be, both in lives lost and property destroyed. The costs of wind damage to the built environment from wind hazards continue to increase, even when adjusted for inflation. These devastating events were only the most recent examples of the worldwide impact of windstorms.

According to a report published by RAND[1], windstorms caused almost two-thirds of the $145B total 2004 uninsured losses. The State of Florida was struck by four hurricanes in 2004, and uninsured losses there alone reached $42B. Losses due to windstorms include damages from wind, storm surge and flooding. The RAND report indicates that, in the United States, losses due to hurricanes and tornadoes total $6B per year.

Although these losses show an increasing trend over the last decade, improvements in forecasts, preparation and mitigation have significantly reduced the number of lives lost over the last century. Deaths and injuries from wind-hazard extreme events, as estimated before Hurricane Katrina, average about 100 deaths and 1,250 injuries per year. Social vulnerability analysis has shown that demographic subpopulations, including those of lower socioeconomic status, are at higher levels of risk from wind events.

3.2 PREVIOUS WIND IMPACT REDUCTION EFFORTS

Improved wind forecasting, wind characterization, wind engineering and design, improved building standards and codes, and mitigation activities, have led to a better understanding of wind hazards, and helped reduce their effects on the built environment.

Social sciences, research for the past fifty years has focused upon producing more effective hurricane and tornado warnings and protective actions on the part of local officials and individuals. Research has led to significant strides in understanding the warning process and implementing effective risk communication. Improved hurricane evacuation planning is the direct result of research over the past thirty years. Thousands of lives may have been saved by improvements in warning and evacuation to date. But, given the devastating impacts of the 2005 hurricane season, clearly more improvements must be made.

Research into individual protective actions also has improved public response to tornadoes. Decades of research on community emergency preparedness and response have produced more effective state and local capabilities. It is an ongoing process to maintain effective capabilities at the state and local level.

Key Federal agency players include:

- Federal Emergency Management Agency (FEMA)
- National Oceanic and Atmospheric Administration (NOAA), Department of Commerce
- National Science Foundation (NSF)
- National Institute of Standards and Technology (NIST), Department of Commerce
- Federal Highway Administration (FHWA)

- Housing and Urban Development (HUD)
- National Aeronautics and Space Administration (NASA)
- U.S. Army Corps of Engineers (USACE)

Also playing a critical role are:

- State governments
- County governments
- City governments
- State-supported public universities

Finally, non-government organizations also continue to play significant roles:

- American Association of Wind Engineers (AAWE)
- American Society of Civil Engineers (ASCE)
- Institute for Building and Home Safety (IBHS)
- Private universities

3.3 RECENT PREPAREDNESS AND MITIGATION ACTIONS

Hurricane Katrina set records for a single disaster event and early indications are that preparedness and mitigation prior to this event were not adequate. The State of Florida had a record hurricane year in 2004 emphasizing the fact that, while some progress has been made in mitigation measures to protect lives and property, much remains to be done. A recent survey conducted by IBHS found that more than half of Florida's homeowners have taken action to protect their homes from hurricanes and an even larger number recognize the importance of the state's building codes in reducing property losses from these events. Many think the codes should be even stronger. States, such as Texas, are adopting hurricane coastline wind load building codes and these are being implemented at the county and city levels. NOAA All-Hazards Radio and the National Weather Service's StormReady program are encouraging preparedness. Advances in wind engineering and design are increasing the effectiveness and popularity of affordable shelters, such as in-residence tornado shelters, based on design and construction guidance developed by FEMA.

4. CURRENT ACTIVITIES AND CAPABILITIES

Several Federal agencies have missions and mission capabilities that are essential to achieving the objectives of the National Windstorm Act. (See Appendix C for Federal agency-specific contributions.) It is difficult to estimate the amount of money that Federal agencies invest in wind hazard related activities alone because of the broad nature of agency missions. Understanding wind events, assessing wind damage, reducing the impacts and enhancing community resilience are often part of larger efforts to understand severe weather, hurricanes, building safer structures, etc. These larger efforts have myriad purposes, of which wind is often a tiny piece, and almost never the primary motivator. Therefore, the total investment by Federal agencies that can be explicitly and solely applied to wind hazard reduction is quite small in relation to the magnitude of losses and the national impact of those losses.

4.1 UNDERSTANDING, PREDICTING AND FORECASTING WINDSTORM HAZARDS

Federal agency efforts to understand, predict, design for, and forecast windstorm hazards range from basic research funded by NSF and operational forecasts provided by NOAA to evacuation studies jointly funded by FEMA and USACE. NIST and FHWA focus on research aimed at understanding, predicting and designing for wind effects on structures, critical infrastructure, and creating the knowledge needed to develop improved design code provisions. NASA's work provides satellite based observational data and develops new observing systems that help underpin and improve wind predictions and forecasts. FEMA provides State and local governments the tools and products to enhance their capability to effectively manage loss reduction programs.

The focus on understanding and predicting of windstorm hazards and risks within any one of these agencies is minimal at this time. Wind is only one relatively small component of a broader suite of hazards addressed by each agency. For example, the observations of NOAA and NASA and the forecasts from NOAA address temperature, precipitation, moisture, air pressure and wind. However, the wind measurements taken are seldom at the small space and time scales required by engineers. In addressing hazards, FEMA, NIST and FHWA address issues related to buildings and public infrastructure for mitigating earthquakes, floods, fires, wind and other hazards making wind just one small component of their overall responsibility.

Nevertheless, efforts by these agencies have led to some improvements in the understanding and prediction of the winds themselves and in the development of programs for mitigating their effects. The spatial and temporal scale of wind predictions are decreasing and becoming more accurate. There has been a gradual increase in the understanding of structural response to winds, but progress has been uneven, particularly in the area of high winds combined with storm surge, flying debris, and ice loading on structures, among others. Another area where more attention is needed is the transfer of current research and knowledge into effective guidance and practice, including cost-effective mitigation.

4.2 ASSESSING THE IMPACT OF WIND HAZARDS

The investigation of wind-induced damage to buildings and critical infrastructure should happen immediately following a wind-hazard event. These assessments of wind impacts are essential to providing new knowledge about how wind behaves at varying elevations and around differing structural envelopes. To assess impact of wind hazard loadings on structures and to gain better understanding of the impact of winds and windstorm on their performance, it is essential to gather data through instrumentation before and field data collection after the hazard event. Through these types of efforts new or enhanced test procedures, tools for predicting structural response to wind and models for computer simulation of wind/structure interaction and loss estimation and improvements in design can become available. Damage assessment is also a focus of social science research as well as household, business and community recovery, but is not necessarily wind related.

4.3 REDUCING THE IMPACT OF WIND HAZARDS

Successfully reducing the impact of wind hazards requires that actions be taken, directly or indirectly, to change or enhance existing building practices, infrastructure resilience, social behavior patterns and evacuation processes. Improvements in warning systems, evacuation planning and building technology have reduced the threat of windstorms to people even while the total number of people, buildings and critical infrastructure exposed to windstorms has grown dramatically. The result is that even while the threat of injury or death is being reduced, the total amount of damage and loss continues to rise. Many improvements have been implemented but much more needs to be done. Techniques have been developed to estimate wind effects that account realistically for wind directionality characteristics. Further, estimation methods have been developed to help assure higher safety levels for tall buildings that experience dynamic effects. The continuing improvement of the Nation's model building codes and standards with respect to improved design and construction provisions for wind resistance have had a significant impact on building and infrastructure performance. Ongoing efforts to develop performance based approaches to building design, especially critical and essential facilities, promise to bring further improvements. The additional development and use of innovative computer-intensive, user friendly methods to quantify wind loading can reduce errors in the estimation of wind loads by as much as fifty percent and can result in stronger structures built for lower costs. This is of interest to the private sector, state and local government, as well as Federal agencies, including FEMA and USACE, which are focused on increasing building survivability through optimized designs, building in hostile environments, and in hurricanes and other wind storms.

New designs that are evaluated in wind tunnels to ensure safety and performance are reducing the impact of winds and windstorms on highway structures. Efforts also have been made to promote structural health monitoring which permits evaluation of changes within a structure over time as a way to determine degradation before a catastrophic event and to incorporate monitoring instrumentation into major new structures.

4.4 PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

Preparedness is the advance capacity to respond to the consequences of a hazard event. This means having emergency plans in place concerning what to do and where to go if a warning is received or a hazard is observed. FEMA, in partnership with NOAA and USACE, develops the tools and products to develop effective State and local plans for evacuation and sheltering. NSF undertakes basic research on warning, evacuation, emergency planning and response, and vulnerability analysis.

Community resilience, especially in vulnerable populations, can be enhanced through a variety of means including outreach and awareness programs, partnerships with Federal and State agencies to improve the resilience of buildings and infrastructure, increased preparedness exercises, effective mitigation planning efforts, and through improvements in local building code adoption and enforcement activities.

Numerous informational and educational materials exist on protection of individuals and property in high wind events, including hurricanes, tornadoes and straight line winds from thunderstorms. This information is repeated in brief during severe weather warnings. Coastal regions impacted by wind are encouraged to be prepared, have mitigation plans in place and establish sound building practices.

Within NOAA's National Weather Service, an outreach and education program called StormReady (http://www.stormready.noaa.gov/) has now reached communities in all 50 States. StormReady helps arm America's communities with the communication and safety skills needed to save lives and property– before and during the event. Working with local emergency managers, the Weather Service helps communities strengthen local safety programs. All potential weather risks to a community are included. Wind is usually a significant risk to life and property in most locations.

In addition, social science research that includes social vulnerability analysis as well as organizational and community emergency preparedness and response has been sponsored by NSF.

5. GAPS

5.1 UNDERSTANDING, PREDICTING AND FORECASTING

There are a number of areas where additional knowledge and action may reduce the impact of windstorms. Among these are enhanced full-scale wind measurement and structure performance with more sites and broader distribution, better and more robust instruments and networking, improved coordination between agencies and jurisdictions and setting standards for sensors, deployment, measurements and data storage.

Fundamental research on the meteorological aspects of wind hazards is continuing under support from NSF and other agencies. The interagency U.S. Weather Research Program has placed a high priority on improved knowledge of hurricane dynamics and developing improved forecasts of hurricane intensity. Major gaps in this research arena include the need for better understanding of the influence on intensity of: ocean heat content; environmental wind and thermodynamic structures and internal hurricane dynamics, such as the impact of hurricane eye wall and rain band interactions.

Improved prediction of wind storms is essential, but almost totally lacking are observations and understanding of the small scale wind structure in time and space to which the built environment responds within a larger windstorm event. Simulation of such detailed wind structure in wind tunnels is useful, but observations in the real environment near full-scale buildings must be obtained. These observations will provide necessary information on the interaction between individual structures and various types of complex built environments on the one hand and high winds on the other.

Methods and tools for wind hazard exposure predictions are required for structural design purposes. Improved methodologies for site-specific wind climate models and more refined and locally-detailed wind speed/hazard maps are therefore a critical need.

5.2 ASSESSING THE IMPACT OF WIND HAZARDS

Tools for assessing the impact of wind hazard events should be developed and improved. A greater effort must be made to study and learn from the aftermath of wind events and investigations of wind-impacted structures should be enhanced by including a broader spectrum of structures, including critical infrastructure. More comprehensive data on wind and windstorms should be collected and data exchange on damage and loss should be encouraged. New methods to predict the risk or loss and damage due to windstorms should be developed with appropriate simulation and modeling tools. Improved understanding of the effects of wind-borne debris on structures as well as the additional risk to structures from wind-driven rain, ice and hail are other important issues. For instance, the wind (speed and turbulent structure) and icing thresholds of danger to these buildings and infrastructure is not well understood.

Social scientists should examine the impact of wind hazards on individuals, businesses and communities, including vulnerable populations, by leveraging National Science Foundation funding to universities and non-government organizations.

Improved methods for assessing social and economic costs are also needed. Inclusion of detailed loss data from the insurance industry in this assessment effort is of vital importance.

5.3 REDUCING THE IMPACT OF WIND HAZARDS
New, more accurate methods of understanding and assessing risk perception, risk communication, risk management, and designing for wind will reduce the impact of wind hazard events. Systematic establishment of design and retrofitting requirements should continue and a closer partnership between the design, construction and industry communities should be established to allow exploration, development and application of innovative technologies. Another area of emphasis should address ongoing programs to ensure that State and local knowledge and capabilities regarding wind hazards are high. Improvement in building code provisions and in wind loading provisions such as those contained in the ASCE 7 Standard is a central part of the impact reduction effort. Improved enforcement of new and existing building code requirements in areas of high risk to wind-borne hazards is equally important. Improved enforcement and inspection by local building officials is a very effective way to decrease the potential for damage from improper construction. Attention to damage generated by wind driven missiles and debris on building envelopes and glazing systems is needed.

5.4 PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE
Information regarding risk and preparedness should be broadly distributed in a coordinated fashion. Gaps include the lack of sufficiently effective decision making tools for warning and evacuation; increased understanding of household and community adoption of preparedness measures; improved understanding of the role of improvisation and resilience in emergency preparedness and response; increased understanding of community physical, economic and social recovery from wind related disasters.

Additional work is needed to understand how individuals, especially those in vulnerable populations, perceive their risk to wind hazards and how they might best receive warning messages. This knowledge will help individuals understand their likelihood of preparedness and the potential need to target messages to specific audiences and geographical locations.

As with any other kind of disaster, community resilience is further determined by how quickly essential services are restored after a wind event. Damage resistant infrastructure must be designed and new technical methods must be developed for rapid repair of damaged infrastructure and restoration of services. Without restoration of essential services, like electricity and gas for cooking, potable water for drinking or telephone lines for communication, extreme community disruption will occur.

6. RECOMMENDATIONS

In accordance with the legislation, a coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, will improve the understanding of windstorms and their impact, and develop and encourage implementation of cost-effective mitigation measures to reduce those impacts while promoting community resilience. We recommend a coordinated, comprehensive multi-agency, multi-disciplinary working group be established as a working group of the National Science and Technology Council's Committee on Environment and Natural Resources Subcommittee on Disaster Reduction to reduce the impact of wind hazards by facilitating better communication between agencies, effectively allocating collective resources and operating within a common framework. This working group shall meet at least quarterly, report to the Subcommittee on Disaster Reduction annually and work with state, local officials and non-government organizations as appropriate. All Federal agencies contributing to this document shall be members of the working group and the chair of the working group will rotate between NIST, NSF, NOAA and FEMA with each Agency serving a two-year term as chair.

A coordinated portfolio of research and other activities should build on existing efforts and should include:

- Assessing individual and community capability to respond to wind events, including vulnerability analyses, risk perception, risk communication, risk management, communication of wind warnings and public response, evacuation capability, and public knowledge of appropriate protective actions for wind events, especially among vulnerable populations
- Evaluating the response of the built environment and critical infrastructure to wind events by investigating aerodynamic response, load path, ultimate capacity and the performance of the building envelope
- Assessing the impact of wind and windborne debris or wind and water/ice/snow
- Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
- Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
- Developing new technologies and ground, airborne and satellite based observing systems to improve knowledge and understanding of windstorms and the wind variability within those storms
- Measuring the response of bridges and other highway structures to wind events, including stability, serviceability and functionality leading up to and through extreme events
- Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services

There could be improvements in and enhancement of:

- Windstorm prediction
- Local, state, regional and federal coordinated response capabilities following wind hazard events, including field validation and data collection capabilities for buildings, critical infrastructure and essential facilities
- Windstorm damage and loss estimation modeling tools
- Standards and technologies that will enable cost-effective, state-of-the-art windstorm-resistant provisions to be adopted as part of state and local building codes

These improvements and enhancements would enable more effective:

- Local, state, regional and federal coordination in response to wind hazard events
- Evacuations through more informed planning and annual drills
- Local and regional preparedness through public-private partnerships fostering outreach and technology transfer programs
- Windstorm impact reduction practices through training and outreach programs that enhance state and local capabilities

APPENDIX A: ELEMENTS OF DISASTER RISK REDUCTION AND HAZARD MANAGEMENT

The hazard research and management community employs a range of terminology to describe its activities, but no definitive, comprehensive list of these terms and their definitions exists. However, hazard risk reduction and disaster management activities can be grouped largely under nine broad concepts: research and development, hazard identification, risk assessment, risk communication, prediction, mitigation, preparedness, response, and recovery. Each of these rubrics includes critical science and technology elements, and, taken together, they form the nation's toolbox for reducing vulnerability to disaster risk.

1. Disaster Process Research and Development (R&D)—the science activities dedicated to improving understanding of the underlying processes and dynamics of each type of hazard. R&D includes fundamental and applied research on geologic, meteorological, epidemiological, and fire hazards; development and application of remote sensing technologies, software models, infrastructure models, organizational and social behavior models, emergency medical techniques; and many other science disciplines applicable to all facets of disasters and disaster management.

2. Hazard Identification—determining which hazards threaten a given area. This includes understanding an area's history of hazard events and the range of severity of those events. The continuous study of the nation's active faults, seismic risks, and volcanoes are included in this category, as are efforts to understand the dynamics of hurricanes, tornadoes, floods, droughts, and other extreme weather events.

3. Risk Assessment—determining the impact of a hazard or hazard event on a given area. This includes advanced scientific modeling to estimate loss of life, threat to public health, structural damage, environmental damage, and economic disruption that could result from specific hazard event scenarios. Risk assessment takes place both before and during disaster events.

4. Risk Communication—public outreach, communication, and warning at every stage of hazard management. Risk communication includes raising public awareness and effecting behavioral change in the areas of mitigation and preparedness; the deployment of stable, reliable, and effective warning systems; and the development of effective messaging for inducing favorable community response to mitigation, preparedness, and warning communications.

5. Mitigation—sustained actions taken to reduce or eliminate the long-term risk to human life and property from hazards based on hazard identification and risk assessment. Examples of mitigation actions include planning and zoning to manage development in hazard zones, storm water management, fire fuel reduction, acquisition and relocation of flood-prone structures, seismic retrofit of bridges and buildings, installation of hurricane straps, construction of tornado safe rooms, and flood-proofing of commercial structures.

6. Prediction—predicting, detecting, and monitoring the onset of a hazard event. Federal agencies utilize weather forecast models, earthquake and volcano monitoring systems, remote sensing applications, and other scientific techniques and devices to gather as much information as possible about the what, when, and where of a potential hazard, as well as the severity of each threat.

7. Preparedness—the advance capacity to respond to the consequences of a hazard event. This means having plans in place concerning what to do and where to go if a warning is received or a hazard is observed. Communities, businesses, schools, public facilities, families, and individuals should have preparedness plans.

8. Response—the act of responding to a hazard event. Hazard response activities include evacuation, damage assessment, public health risk assessment, search and rescue, fire suppression, flood control, and emergency medical response. Each of these response activities relies heavily on information and communication technologies.

9. Recovery—activities designed to restore normalcy to the community in the aftermath of a hazard event. Recovery activities include restoring power lines, removing debris, draining floodwaters, rebuilding, and providing economic assistance programs for disaster victims. As with response, the recovery process relies heavily on the availability of up-to-date data and information about the various community sectors, and on the technology to obtain and communicate that information.

APPENDIX B: REFERENCE

1. Meade, C. and Abbott, M., "Assessing Federal Research and Development for Hazard Loss Reduction", RAND Report, 2003, 65pp.

APPENDIX C: CURRENT AGENCY ACTIVITIES

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
Understanding, Predicting and Forecasting							
Enhancing knowledge, information and data on severe winds	Un-Knows description of wind increase with height; work on wind turbulence; post-event documentation and damage analyses	Better understanding of atmospheric dynamics of straight-line winds	Wind observing systems and analysis	Post-event building performance assessments	Experimental and modeling research to improve understanding of severe storm development and lifecycle	Effects of wind on water and storm surge	Monitored and evaluated wind conditions at bridge sites; deployed weather stations along highways
Improving prediction of hazardous wind events	Developed extreme wind climatological models	Tornado-genesis and tornadic vortex structure	Wind speed and direction forecasts		Work with NOAA to develop new technologies and use existing scientific satellite observations to improve wind storm prediction		Evaluated wind data and characterized wind and storm conditions at bridge sites
Understanding and quantifying wind loading	Developed novel static and dynamic wind loading estimation techniques	Improved understanding of fundamental physics that control hurricane intensity		Post-event building performance assessments			Measured wind conditions and structural response; studied wind/structure interaction
Understanding the perception of wind hazard risk		Studies of hazard risk perception		Outreach and training	Satellite observations provide global context to illustrate wind storm hazard risk to the public		Studied user/owner perception of risk
Mapping wind hazards	Developed techniques for improved extreme wind speed maps	Investigation of straight-line winds	Wind speed and direction analysis for input to HAZUS and other tools		Satellite observations from Landsat, EOS provide capability to map potential high risk regions		
Assessing Impacts							
Investigating wind resistance of buildings, structures and critical infrastructure	Pioneered studies of structural ultimate capacity and dynamic response under fluctuating wind loads. Post-event damage analyses.	Rapid response field investigations of structural and societal damage		Post-event building performance assessments			Conducted aerodynamic assessment of new bridge designs in the laboratory; evaluated structural performance through full scale measurements
Developing improved tools for component- and structure-level simulation and numerical modeling of wind effects	Developed technology for computer-intensive use of pressure time histories for structural design	Development of instrumentation for the observational study of atmospheric winds					Developed methods for simulations in laboratory; developed numerical models for predicting bridge response

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
Assessing Impacts (continued)							
Developing improved tools for loss assessment of wind hazards	Assisted the State of Florida in developing such tools	Design analyses for storm surge, wave actions, and wind speed on structures		Developing hurricane loss estimation model (HAZUS)	Ground, air and satellite based scientific observations provide capability to assess pre- and post-storm impact	Empirical models for debris volume estimation	
Assessing social costs		Economic analyses of wind disaster impacts		Benefits of mitigation study, developing indirect economic loss model			
Reducing Impacts							
Assessing and communicating risk	Incorporated effect of uncertainties on safety margins for wind loads	Basic research on warning and risk communication	Airborne photos and Lidar data for damage assessment; watches and warnings for high wind events; NOAA all hazards radio	Developing hurricane loss estimation model (HAZUS); Design and construction guidance			Developed new procedures for performing aerodynamic assessments
Developing prototype structural requirements		Improved modeling of wind effects upon structures		Consensus design standard input		Guidelines and requirements for standing seam metal roofing, building survivability and optimized design	Identified details important to structural performance in winds
Demonstration, education, training and outreach on improved codes and building guidelines	Participant in the ASCE 7 Standard Committee on Wind Loads; trains future wind engineers	Research on Code enforcement and code design analyses		Develop design and construction guidance; Outreach and training		Snow fence construction to reduce wind impacts in cold regions	Disseminated issues to visitors at laboratory, presented findings at major conferences
Guidance on retrofitting	Provides research, sponsored workshop	Analyses of effectiveness of structural retrofitting		Develop design and construction retrofit guidance			Evaluated structures demonstrating wind problems; developed retrofit solutions
Innovative technologies	Developed Database-Assisted Design methodologies; estimated ultimate capacities through non-linear analysis	Structural health monitoring				Wind noise mitigation	Investigated streamlining of structural form, aerodynamic treatment of structural surfaces, use of dampers and damping materials, use of active/passive control systems
Land use measures and cost effective construction practices		Research on effectiveness of non-structural mitigation		Develop/promote wind resistant construction guidance		Design guidance on structural issues	

	NIST	NSF	NOAA	FEMA (DHS)	NASA	USACE	FHWA
Preparedness and Enhancing Community Resilience							
Developing tools for community preparedness to wind hazards		Research on community emergency preparedness and response capabilities,	StormReady community program	Develop tools for effective State and local evacuation and sheltering plans; implementation and training for design and construction guidance including HAZUS			
K-12 and college education needs	Trains future wind engineers	Research on emergency management education	Tornado and hurricane educational materials	Develop public outreach materials; materials for university courses; HAZUS training	NASA Earth science educational outreach programs increase understanding and awareness of wind storm hazards and impact		Conducted demonstrations and tours for students visiting the laboratory; presented seminars at universities as requested
General public awareness and outreach	Issues recommendations for wind engineering research	Surveys of public risk perception and knowledge of protective actions	Pre-tornado and pre-hurricane season public awareness campaigns	Develop public outreach materials; materials for university courses; HAZUS training			
Evacuation Planning		Evacuation Research and Decision Tool development		Develop tools for effective State and local evacuation and sheltering plans		Cooperative evacuation route development	Participate with the State Highway Agencies in evacuation planning for all hazards
Enhancing disaster resistance of Building Codes and Standards		Code analysis and studies of enforcement		Facilitate improvements to national model building codes and standards			
Building public and private partnerships				Maintaining and enhancing partnerships with Agencies, Universities, and private sector		Involvement with TDP and other public-private groups	
Conducting emergency response exercises		Basic research on emergency response		Emergency response and preparedness exercises thru FEMA Preparedness Division		Active exercise program	Conduct regular emergency response exercises for all hazards

APPENDIX D: AGENCY SUMMARIES

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

UNDERSTANDING, PREDICTING AND FORECASTING

NIST researchers have proposed a uniform description of the variation of wind speeds with height to supersede two descriptions currently in use: the logarithmic law, used by meteorologists, and the power law, used by the ASCE 7 Standard. The current dichotomy makes it difficult to transfer knowledge from the meteorological community to the structural engineering community. NIST has also performed work on wind turbulence spectra, and has shown that efforts to develop overly detailed turbulence descriptions may be unnecessary for a broad class of structural calculations.

NIST conducts research aimed at developing extreme wind climatological models, both non-directional and directional, aimed at estimating extreme speeds with long mean recurrence intervals.

NIST develops and uses innovative computer-intensive, user-friendly methods to quantify wind loading, e.g.: NIST has developed database-assisted design, an advanced approach to defining wind loads on buildings which is based on information obtained in wind tunnel tests. This is expected to reduce errors in the estimation of wind loads by up to 50% and to result in stronger structures at lower costs. In addition, these methods are used in conjunction with nonlinear structural analysis techniques to develop the technology required for alternate capacity-based design that could save up to 10% or even more in construction steel consumption nationwide while reducing expected losses due to winds. This development is of potential interest to those entities with an interest in "greener" building technology and embodied energy reduction. NIST develops techniques for the estimation of wind effects that account realistically for wind directionality characteristics, and develops estimation methods to help assure higher safety levels for tall buildings that experience dynamic effects.

Through its extreme wind climatological work NIST has contributed to efforts to improve the mapping of hazards due to non-hurricane winds, hurricanes, and tornadoes.

ASSESSING IMPACTS

NIST investigates wind-induced damage that can provide new knowledge or recommendations for improvements to codes, standards, and practices that will reduce public risk and economic losses in future. The post-disaster investigations conducted by NIST have led to changes in practices, standards, and codes to enhance the health and safety of the American public. Examples include:

- Improvements to the wind speed requirements for coastal and near coastal regions and anchoring provisions for manufactured (mobile) homes in the Department of Housing and Urban Development national regulatory standards following Hurricane Andrew which struck Florida in 1992 and Hurricane Camille which struck Mississippi in 1969.

- An investigation following the Jarrell, TX, tornado of 1997 led to the development of an enhanced Fujita (EF) scale for tornado intensity (used to estimate wind speed based on observed damage to physical structures) by the Working Group for Natural Disaster Reduction/Post-Storm Data Acquisition in the Office of the Federal Coordinator for Meteorology (which includes NIST as a member) and subsequently has received approval by the National Weather Service for implementation during the Spring 2006 severe weather season.

Further, NIST's program for Hurricane Reconstruction in the Dominican Republic after Hurricane Mitch and Georges (1998), in partnership with USAID and HUD, led to the development of (1) a guide for constructing disaster-resistant housing in the informal sector, and (2) a manual for evaluating the disaster resistance of critical facilities (especially concrete buildings). To disseminate this work among practitioners, training workshops were conducted for local builders on the application of the housing guidance and for local engineers on the application of the facility assessment manual.

As part of its broader mission to meet the measurement and standards needs of the building and fire community, NIST is engaged, singly or in cooperation with other institutions, including NOAA, in wind speed measurements, specialized use of existing data, modeling, and prediction. These efforts are aimed at characterizing the wind environment and the wind climatology near the Earth's surface that are needed for realistic engineering assessments of structural safety, dispersion of fire products, and fire growth and spread. NIST also develops software for the user-friendly utilization of NOAA's ASOS data to create sets of wind speeds in formats suitable for extreme value analyses, and develops and disseminates the most advanced techniques for such analyses. The techniques are validated by using Monte Carlo simulations to estimate the effect of non-asymptotic behavior. NIST also assists the ASCE 7 Standard Task Committee on Wind Loads in developing realistic, updated U.S. wind hazard maps.

NIST is part of the team that develops the Florida Public Loss Prediction model at the request of the Florida Department of Financial Services. Through nonlinear analysis, NIST also develops novel algorithms for prediction of incipient wind-induced structural collapse or damage to building envelope components.

NIST has conducted studies of ultimate capacities of structures under fluctuating wind loads which, if continued, will facilitate safer structures while at the same time reducing material costs and embodied energy.

NIST investigates the systematic use of database-assisted design wherein pressure time histories throughout the building envelope are recorded in electronic form for use in the design process. NIST also has the capacity to develop computational fluid dynamics tools for use in wind engineering.

REDUCING IMPACTS

NIST has capabilities in the area of risk assessment, and has worked on the development of appropriate safety margins for wind loads.

NIST is represented and active in the ASCE 7 Standard Committee on Wind Loads, and provides training to several high-school, undergraduate, graduate students, and postdoctoral research associates per year in the area of wind engineering.

NIST has supported the development of retrofitting guidance both through its research and by holding a workshop on the subject.

NIST has developed several innovative technologies in wind engineering, e.g., Database-Assisted Design methodologies, estimation of ultimate capacities through non-linear analysis, methods for simultaneously taking into account the directionality of the extreme wind climate, of the building's aerodynamic and dynamic response.

PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

Through its investigations NIST has issued recommendations for research and implementation of existing knowledge in a variety of wind-engineering areas. For example, NIST's investigation of the World Trade Center towers' collapse of 9/11 found that there were discrepancies on the order of 40% between wind tunnel testing laboratories which estimate wind loads on tall buildings. The labs that were compared were independent labs that are widely used by industry. NIST has recommended that nationally accepted performance standards be developed for: (1) conducting wind tunnel testing of prototype structures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.

NIST has also recommended that an appropriate criterion be developed and implemented to enhance the performance of tall buildings by limiting how much they sway under lateral load design conditions (e.g., winds and earthquakes).

NIST provides training to several high-school, undergraduate, graduate students, and postdoctoral research associates per year in the area of wind engineering.

NATIONAL SCIENCE FOUNDATION

UNDERSTANDING, PREDICTING AND FORECASTING

The National Science Foundation (NSF) invests a considerable amount of resources in support of competitive peer-reviewed research aimed at defining the wind environment physically and statistically. NSF has awarded grants for research related to hurricanes, tornadoes, cyclones, and wind. This research is mainly undertaken by the Directorates of Engineering, Geosciences and Social, Behavioral and Economic Sciences.

The Division of Atmospheric Sciences at NSF supports research that covers a broad range of activities relevant to wind hazards. Current research activities include: developing improved understanding of the fundamental physics that control hurricane intensity; research on tornado genesis and tornadic vortex structure; investigations of strong straight line winds from thunderstorms. Better understanding of the atmospheric dynamics of straight-line winds was one of the foci of the Bow Echo and Mesoscale Convective Vortices Experiment (BAMEX) held in the Spring of 2003.

ASSESSING IMPACTS

In addition to research in atmospheric dynamics, the Atmospheric Sciences Division supports development of instrumentation (e.g. mobile and airborne Doppler radars) that is required for the observational study of atmospheric winds.

Structural Engineering research funded by NSF has examined the immediate impact of hurricane and tornado activity by funding damage assessment teams to visit disaster areas for post-event triage of structures. These studies are valuable in identifying not only specific anecdotal damage examples but also issues that require further study. For example, uneven damage patterns were observed by NSF-funded teams responding to Hurricane Isabel in 2003. The damage patterns suggest that the peak winds speeds were highly variable as the storm moved inward from the Atlantic Ocean. NSF-funded research is currently developing models for the storm surge and wave actions generated by severe storms and hurricanes. Other research is focused on detailed wind tunnel studies of structures under a variety of wind environments to determine the adequacy of current design and modeling approaches.

Social science research at NSF has supported quick-response research efforts to assess community damages, infrastructure disruption, and individual, organizational, and community social, political and economic impacts. The research attempts to develop damage assessment tools for use by emergency response officials.

REDUCING IMPACTS

Development of improved modeling of wind effects on structures is a primary outcome of NSF-funded Structural Engineering research. Present design standards, such as ASCE 7, have benefited greatly by Federally-funded research into wind and its effects on structures. The current versions of these consensus standards are more comprehensive than previous versions. However, at the present time, most large structures including longer span bridges are subjected to detailed wind tunnel studies to determine the impact of winds on the structure and how to optimize their performance. It is the goal of NSF-funded research to improve the modeling and analysis capabilities in the Engineering community so that in the future, these detailed experimental studies will not be required. This will require on-going improvements in computational systems as well as in the modeling and analysis of the aeroelastic effects of wind. Training of the next generation of Wind Engineers is another aspect of NSF funding that is important. As the founding generation of Wind Engineers has retired, it has become an urgent need to continue the training of young Engineers so that the Wind Community will be able to meet the challenged posed by society in reducing wind effects on the built environment. NSF support for universities engaged in Wind Engineering research is a key component in building of the next generation of Engineers.

PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

NSF has a long history of supporting social science research on risk communication, warning systems and processes, evacuation planning and effectiveness, and individual, organizational and community protective actions undertaken prior to impact. In addition, research on factors facilitating societal adoption of structural and non-structural mitigation measures has been supported for over two decades. Research has also been supported that focuses upon such elements of community preparedness and capabilities improving our understanding and developing tools to measure social vulnerability and damage assessment, and household, business and community recovery from wind disasters.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

UNDERSTANDING, PREDICTING AND FORECASTING

NOAA maintains an investment, on the order of $600M in its operational numerical weather prediction and forecasting activities within the National Weather Service (NWS). These products include wind forecasts and severe weather outlooks up to 2 and 3 days. In addition, NOAA funds research to improve numerical modeling and forecast decision support systems (about $20M). Much of the research is done within NOAA research laboratories in close collaboration with the NWS, and includes work to improve detection, diagnosis, real-time and retrospective analysis, and forecasts of hurricanes, tornadoes and thunderstorms. The NOAA H*WIND product provides a contoured map of analyzed surface winds for hurricanes before, during and after landfall. In support of its modeling, prediction, and forecasting efforts, NOAA supports and maintains an array of surface wind sensors, radar and satellite observation systems, and mobile tornado tracking, observation, and measurement systems, including the WSR-88D Doppler radars operated with the FAA, and the COOP network. In addition, NOAA research develops and tests new observing capabilities, including airborne microwave wind sensors, GPS sounding technology, Doppler wind Lidar, and radar wind profilers. A new extreme turbulence probe uses pressure ports to measure high velocity winds at high frequency, which has been successfully used during 2004.

ASSESSING IMPACTS

NOAA provides photographic and on-the-ground damage surveys immediately following a disaster to determine the severity of the impact of each storm and to provide information that assists in response and recovery. These surveys are particularly useful to correlate the measured winds with the degree of damage. The NOAA Sea Grant program funds real-time hurricane wind measurements and instrumented test homes in coastal environments, assessments of building practices and plans in coastal regions that include wind effects, and education and outreach concerning preparedness and mitigation practices.

PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

Within NOAA, the National Weather Service provides numerous informational and educational materials on protection of the general public and property in high wind events, including hurricanes, tornadoes and straight line winds from thunderstorms. This information is repeated in brief during severe weather warnings. The Sea Grant program, through extension agents, offers education and outreach concerning best construction practices and sighting of coastal development.

FEDERAL EMERGENCY MANAGEMENT AGENCY[1]

UNDERSTANDING, PREDICTING AND FORECASTING

Mitigation Assessment Team (MAT) studies of building performance following hurricanes have been frequently and successfully used to assess and understand the impacts of wind storms on the built environment. Those lessons learned have been translated into improvements in design and construction practices and changes to the nation's consensus design standards and national model building codes which directly improves the wind-resistance of construction in high-wind areas. Through the use of a state-of-the-art wind field computer model, the HAZUS loss estimation tool allows states and communities to conduct vulnerability analysis which leads to an improved understanding of how windstorms affect the built environment and their risk from those hazards. Also, ongoing outreach and training on wind hazards enhances the knowledge and capability of all groups to make informed decisions.

ASSESSING IMPACTS

Detailed results of HAZUS analysis provide communities, emergency managers, planners, and decision-makers with critical information regarding community vulnerability and likely impacts impending or future hurricanes. This information can have a significant impact on the decision-makers who are responsible for determining what, if any, will be taken before, during, and after hurricanes. Specific assessment activities include:

- Conduct post-hurricane building performance assessments
- Develop HAZUS hurricane wind loss estimation modeling tool
- Conduct a study on the benefits of mitigation; and
- Develop an indirect economic loss model for hurricanes.

REDUCING IMPACTS

A critical, and effective, way to reduce the impacts of hurricanes on the built environment is to have strong, disaster-resistant building codes and in place which effectively enforced. FEMA has worked for over a decade to develop partnerships and successfully advocate for the adoption of wind-resistant provisions to the nation's model building codes and standards. A part of that effort includes participation consensus committees such as ASCE 7 (Design Loads for Buildings and other Structures) Wind Load Task Committee and developing design and construction guidance (new and retrofit) for design professionals, State and local officials, contractors, and the public. We also conduct outreach and training to improve understanding and promote the use of wind resistant design and construction in high-wind coastal areas.

PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

FEMA works to promote the concept of having emergency plans in place concerning what to do and where to go if a warning is received or a hazard is observed. In partnership with NOAA and USACE, FEMA develops the tools and products to develop effective State and local plans for evacuation and sheltering. In addition, we provide support for the development and exercise of community and regional evacuation planning; develop and implement state-of-the-art design and construction guidance; train and educate using materials designed for communities, designers, and contractors; develop public outreach materials; establish and maintain partnerships, grants and cooperative agreements with a wide range of Agencies, trade organizations, universities, and private-sector groups; and

[1] Specific organizational units may vary because of pending reorganization.

carry out a robust program of emergency response and preparedness exercises through the FEMA Preparedness Division.

FEDERAL HIGHWAY ADMINISTRATION

UNDERSTANDING, PREDICTING AND FORECASTING

A significant component of the FHWA wind research program has been the development of technology and capabilities to collect site-specific information on winds and windstorms to gain better understanding of the wind environment. A select number of sites have been instrumented and monitored by the Aerodynamics Laboratory for periods ranging from weeks to decades to characterize the wind conditions and study impact on structures. Roadway Weather Stations have been deployed on many of their major highway routes to monitor wind as well as general roadway conditions.

ASSESSING IMPACTS

FHWA is specialized in the assessment of impact of winds and windstorms on the performance and safety of highway bridges, especially long span bridges, and other highway structures. The agency's Aerodynamics Laboratory has been the primary facility in the U.S. for conducting aerodynamic assessment of new bridge designs and evaluations of existing structures sensitive to wind. Many bridge assessments are also performed at private and public laboratories in Canada, and the results are usually reviewed by FHWA staff. The FHWA Laboratory has been active in developing new or enhanced test procedures, tools for predicting structural response to wind, and models for computer simulation of wind/structure interaction. The Aerodynamics Laboratory also performs full scale measurements on highway structures, in conjunction with wind measurements, to gain better understanding of the impact of winds and windstorms on their performance.

REDUCING IMPACTS

The FHWA wind research program has been working toward reducing the impact of winds and windstorms on highway structures. New designs have been evaluated in the wind tunnel to ensure safety and performance, while retrofits have been identified and implemented for structures with wind problems. Some studies have been initiated to conduct benchmark tests on new structures to establish initial performance characteristics. In addition, efforts have been made to promote structural health monitoring and to incorporate monitoring instrumentation into major new structures. Guidelines are being developed to mitigate wind-induced vibration of cables on long span bridges. Through Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP), AASHTO guidelines for wind related design of highway support structures (signs, signals, luminaries, etc.) have been periodically updated. No national guideline or specification currently exists for the wind resistant design of long span bridges. The FHWA wind research program has just initiated a small project to prepare a synthesis of wind load criteria for long span bridges. Studies are planned to address areas of risk and reliability due to all hazards, including wind.

PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

The FHWA wind research program has attempted to provide some training and awareness to students by providing access to and tours of its research facility in McLean, Virginia. A new demonstration wind tunnel has recently been added to the laboratory to assist in this outreach activity. Some seminars have been presented at selected universities as opportunities arise. More than two dozen graduate students have had the opportunity to perform research in our Aerodynamics Laboratory under the umbrella of the Eisenhower

Fellowship Program with the hope of stimulating interest in pursuit of a career in Wind Engineering. FHWA has provided demonstrations and tours of its facility to groups of engineers, industry representatives, public officials, and the general public when requested. Findings of our investigations are presented in a variety of venues including workshops, seminars, national meetings, and international conferences. FHWA also engages in developing predictive traffic analysis tools for planning and traffic management to improve mobility in times of crisis. Models are being tested which allows engineers to perform critical transportation infrastructure analyses and evaluate different incident management strategies during and after any event. Additionally it participates with State highway agencies in evacuation planning and response for all hazards.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

UNDERSTANDING, PREDICTING AND FORECASTING

NASA operates a number of scientific satellites, including the three flagship satellites Terra, Aqua, and Aura, as part of the Earth Observing System. The EOS instruments provide unique global observations of atmospheric, land and ocean processes that can augment the operational observations of NOAA to improve our understanding of the generation and lifecycle of the large storm systems that produce hazardous wind conditions. NASA satellite observations, when assimilated into operational models, can significantly improve the forecast and prediction of these storms. For measurements of high impact and importance NASA works closely with NOAA and DoD to transition these new measurement capabilities into the next generation of operational weather satellites. Beyond EOS, NASA is also developing new technologies and instruments, including space based precipitation radar and Doppler wind Lidar which will further advance our understanding and capability to predict these events. In addition, NASA is developing advanced global models that can be used for weather prediction and climate simulation; operates, plans, and considers the development of satellite observing systems contributing significantly to the understanding and prediction of windstorms, including space-based Lidar wind profile measurement systems, and the Global Precipitation Mission. NASA performs Observing System Simulation Experiments, typically in collaboration with NOAA, to evaluate the potential of proposed observing systems to contribute to improved forecasts and to design the most effective global observing system.

ASSESSING IMPACTS

NASA land and ocean observing systems such as Landsat, MODIS, and SeaWIFs provide the 'big picture' space based view of the impact of large windstorms in affected areas. This big picture view can allow rapid assessment of the effects on the built environment and have the potential to be used for planning and deployment of available resources to the most heavily impacted regions. Other unique ground and airborne instruments can be employed to determine the patterns and magnitudes of coastal change caused by erosion and destruction of buildings and infrastructure following a windstorm. For example, through a cooperative research program NASA, NOAA, the U.S. Geological Survey and the U.S. Army Corps of Engineers are exploring the use of innovative airborne laser mapping systems to quantify coastal change along the entire coastline affected by Hurricane Katrina.

UNITED STATES ARMY CORPS OF ENGINEERS

UNDERSTANDING, PREDICTING AND FORECASTING

Following Hurricane Katrina, ERDC was contacted to provide calculations relative to the effects of wind on water and surge, key information that can be leveraged into future wind mitigation studies.

REDUCING IMPACTS

USACE is presently concerned with building survivability, optimized building and facility design, building in hostile (particularly cold) environments, and in hurricanes and storms. Research proposals addressing structural issues related to wind have been developed for all three services.

USACE has developed guidelines and requirements for standing metal seam roofing and the Corps' Engineer Research and Development Center has recently conducted research in areas of wind/noise mitigation techniques and techniques for constructing snow fences to reduce the impacts of wind in cold regions.

ASSESSING IMPACTS

Following Hurricane Andrew in 1992, the USACE participated in a reconnaissance effort related to damage at Homestead Air Force Base and lessons learned as a result of that storm. The Corps' Engineer Research and Development Center (ERDC) participated in an effort for federally owned and leased buildings as part of the Seismic Hazard Reduction Program that involved estimating the number of buildings at risk and probable annual loss and the projected cost to mitigate the existing seismic deficiencies in federal buildings. The knowledge gained in the seismic program can be leveraged for a new wind-focused program. A group within USACE is also working on empirical modeling of debris volume created by wind storms and the associated rain.

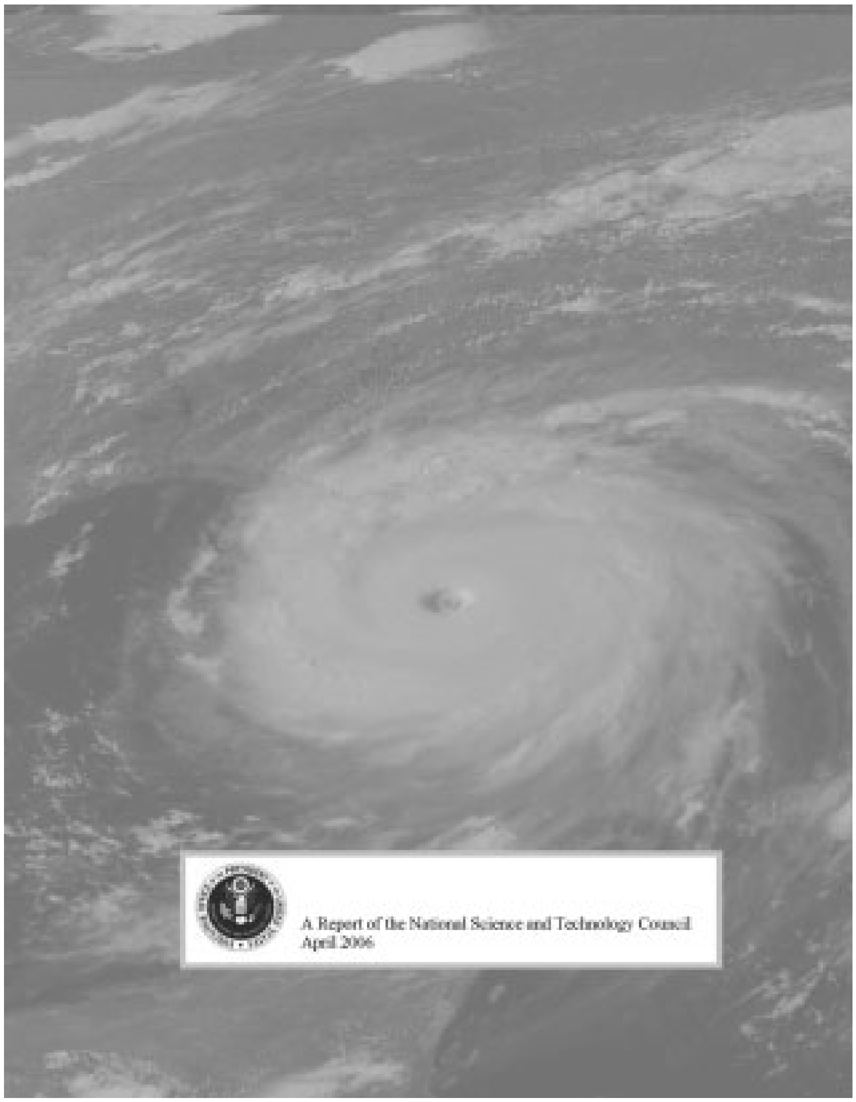
PREPAREDNESS AND ENHANCING COMMUNITY RESILIENCE

USACE participates in cooperative evacuation route development and maintains an active program conducting emergency response exercises.

APPENDIX E: LIST OF ACRONYMS / DEFINITIONS

AASHTO	American Association of State Highway and Transportation Officials
AAWE	American Association of Wind Engineers
ASCE	American Society of Civil Engineers
ASOS	Automated Surface Observing System
ASTM	American Society for Testing and Materials
BAMEX	Bow Echo and Mesoscale Convective Vortices Experiment
COOP	Cooperative Observer Program
DOD	Department of Defense
EOS	Earth Observing System
ERDC	Engineer Research and Development Center
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
HAZUS-MH	HAZUS Meteorological Hazards
H*WIND	Hurricane Wind
HUD	Department of Housing and Urban Development
IBHS	Institute for Business and Home Safety
ICC	International Code Series
MAT	Mitigation Assessment Team
NASA	National Aeronautics and Space Administration
NCHRP	National Cooperative Highway Research Program
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OSTP	Office of Science and Technology Policy
USACE	United States Army Corps of Engineers

Attachment 2



Windstorm Impact Reduction Program
Biennial Progress Report for Fiscal Years 2005-2006

I. Background

The National Windstorm Impact Reduction Program (NWIRP) was established by Public Law 108-360, the National Windstorm Impact Reduction Act of 2004. As required by the legislation, an implementation plan[1] was developed by the Interagency Working Group (IWG) that provided guidance for participating agencies. The legislation also calls for a biennial report to Congress. This document is the biennial report for fiscal years 2005 and 2006.

A. The Significance of Wind Hazards

The 2005 hurricane season - the most costly in U.S. history - produced storms of unusual destruction, causing large-scale damage from wind and water across many states. Hurricanes Katrina, Rita and Wilma demonstrated in dramatic fashion how costly these events can be, both in lives lost and property destroyed. The expense of wind damage to the built environment from wind hazards have been increasing over the past decade, even when adjusted for inflation, as human development increases in the vulnerable coastal zones in hurricane-prone regions. These devastating events were only the most recent examples of the worldwide impact of windstorms.

According to a report published by RAND[2], windstorms caused almost two-thirds of the $145 billion in uninsured losses in 2004. Florida alone suffered $42 billion in uninsured losses from the damage brought by four hurricanes that year. The RAND report indicates that the destruction caused by high winds, storm surges and flooding hurricanes and tornadoes cause throughout the United States cost the nation an average of about $6 billion per year.

Although economic losses have increased over the last decade, improvements in forecasts, preparation and mitigation have significantly reduced the number of lives lost during the last century. Before Hurricane Katrina, the nation averaged about 100 deaths and 1,250 injuries per year. Social vulnerability analysis indicates that demographic subpopulations, including those of lower socioeconomic status, are at higher levels of risk from wind events[3].

B. Objectives

Public Law 108-360, Title II, the National Windstorm Impact Reduction Act of 2004, which was signed into law by President Bush on October 25, 2004, is intended to measurably reduce the loss of life and property from windstorms. The law states that:

The objective is to be achieved through a coordinated Federal effort, in cooperation with other levels of government, academia, and the private sector, aimed at improving the understanding of windstorms and their impacts and developing and encouraging implementation of cost-effective mitigation measures to reduce those impacts.

- *National Institute of Standards and Technology (NIST) shall support research and development to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines.*
- *National Science Foundation (NSF) shall support research in engineering and the atmospheric sciences to improve the understanding of the behavior of windstorms and their impact on buildings, structures and lifelines.*
- *National Oceanic and Atmospheric Administration (NOAA) shall support atmospheric sciences research to improve the understanding of the behavior of windstorms and their impact on buildings, structures, and lifelines.*
- *Federal Emergency Management Agency (FEMA) shall support the development of risk assessment tools and the effective mitigation techniques, windstorm-related data collection and analysis, public outreach, information dissemination, and implementation of mitigation measures consistent with the Agency's all-hazards approach.*

C. The Interagency Working Group and Contributing Agencies

The National Windstorm Impact Reduction Act directed the Director of the President's Office of Science and Technology Policy to *"establish an Interagency Working Group consisting of representatives of NSF, NOAA, NIST, FEMA, and other Federal agencies as appropriate. The Interagency Working Group will be responsible for the planning, management, and coordination of the Program, including budget coordination."*

The Interagency Working Group was reconstituted after the delivery of the NWIRP implementation plan to Congress in April 2006. It consists of representatives from the agencies mentioned and, in addition, the Department of Transportation's Federal Highway Administration (FWHA) and the Department of Housing and Urban Development. The FWHA is the only agency not mentioned in the Act that contributes to this report.

D. The Intersection of Agency Missions with Wind Impact Reduction Objectives

The following agencies have contributed to this report in accordance with the objectives of the National Windstorm Reduction Act.

NSF: NSF supports basic research on the occurrence and effects of most natural hazards. This research includes studies of the temporal and special structure of hurricane winds, straight line winds and tornados and their effects on the built environment. Engineering studies include development of strategies and procedures for assessing and reducing impacts for all types of wind environments. Quantifying risk associated with wind loads and developing models for economic loss estimation and community impact are also important objectives. Another important objective of NSF is to study community preparedness and response to wind events in order to develop effective models for improving community resilience and hazard mitigation.

NOAA: Within NOAA's mission of understanding the environment, providing environmental stewardship, and predicting environmental changes, is the objective of saving lives and property. Wind is one of the many environmental parameters that NOAA strives to better understand and predict due to its often detrimental effect on lives and property. This includes potentially damaging winds caused by tornadoes, hurricanes, and severe thunderstorms. The Hurricane Research Division of NOAA works with NOAA's National Hurricane Center to improve wind forecasts, for example, through the new hurricane wind probability products. The National Severe Storms Laboratory helps NOAA's Storm Prediction Center to improve forecasts of tornadic storms and of strong and damaging winds in severe thunderstorms. As part of the efforts leading to improved prediction, precise wind measurements are required, understanding of the processes producing such winds is improved, as is understanding of the nature (e.g., strength and duration) of strong wind events.

NIST: NIST has a long and effective history in fulfilling its mission of serving the measurement and standards needs of the building and fire safety industries through its Building and Fire Research Laboratory (BFRL). BFRL is a critical source of metrics, models and knowledge for predicting the extent of damage from natural and man-made hazards, mitigating their impact, and helping to prevent failures in communities and public infrastructure systems. NIST's mission in the area of wind engineering has historically been twofold: (1) to create the knowledge needed to improve code provisions and practices resulting in safer and more economical structures and (2) to develop effective tools for use in the prediction and investigation of losses due to wind.

FEMA: Within FEMA's National Earthquake Hazards Reduction Program legislative authority, the Earthquake Hazards Reduction Act of 1977, as amended, it is recognized in Section 2 Findings that earthquake mitigation activities provide collateral benefits to mitigate other natural hazards, including windstorm events. In addition, under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, FEMA coordinates the National Hurricane Program which provides important information, products, and tools to state and local governments in hurricane-threatened areas of the country.

FHWA: The mission of the *Bridge Safety, Reliability, and Security Initiative* is to effectively deal with natural and manmade hazards to existing and new bridges as well as other highway structures. One of the objectives of the *Bridge Program Strategic Plan* is to ensure that highway structures provide a high level of safety and service under all conditions. Highway structures shall provide a high level of service under normal conditions and shall provide specified levels of reliability when subjected to natural and manmade hazards (extreme events).

E. Areas of Focus of the NWIRP implementation plan

As prescribed by Public Law 108-360, Title II, the National Windstorm Impact Reduction Act of 2004, the Interagency Working Group was established in 2004 and delivered the Windstorm Impact Reduction Implementation Plan[1] for the National Windstorm Impact Reduction Program (NWIRP) in 2005. The NWIRP implementation plan organized the body of wind hazard research into the following four major themes with sub-themes:

1. Understanding, predicting, and forecasting
    a. Enhancing knowledge, information and data on severe winds
    b. Improving prediction of hazardous wind events
    c. Understanding and quantifying wind loading
    d. Understanding the perception of wind hazard risk

   e. Mapping wind hazards
2. Assessing impacts
   a. Investigating wind resistance of buildings, structures and critical infrastructure
   b. Developing improved tools for component- and structure-level simulation and numerical modeling of wind effects
   c. Developing improved tools for loss assessment of wind hazards
   d. Assessing social costs
3. Reducing impacts
   a. Assessing and communicating risk
   b. Developing prototype structural requirements
   c. Demonstration, education, training and outreach on improved codes and building guidelines
   d. Guidance on retrofitting
   e. Innovative technologies
   f. Land use measures and cost effective construction practices
4. Preparedness and Enhancing Community Resilience
   a. Developing tools for community preparedness to wind hazards
   b. K-12 and college education needs
   c. General public awareness and outreach
   d. Evacuation planning
   e. Enhancing disaster-resistance of building codes and standards
   f. Building public and private partnerships
   g. Conducting emergency response exercises

The progress in each sub-theme, if any and as appropriate within each agency's mission, is presented in the next section.

Within the four research themes, the NWIRP implementation plan identified eight high priority research topics to be addressed by agency programs:

- Assessing individual and community capability to respond to wind events, including vulnerability analyses, risk perception, risk communication, risk management, communication of wind warnings and public response, evacuation capability, and public knowledge of appropriate protective actions for wind events, especially among vulnerable populations
- Evaluating the response of the built environment and critical infrastructure to wind events by investigating aerodynamic response, load path, ultimate capacity and the performance of the building envelope
- Assessing the impact of wind and windborne debris or wind and water/ice/snow
- Examining the interaction between wind and storm surge to determine the impact on building foundations and critical infrastructure
- Exploring the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation
- Developing new technologies and ground, airborne and satellite based observing systems to improve knowledge and understanding of windstorms and the wind variability within those storms

- Measuring the response of bridges and other highway structures to wind events, including stability, serviceability and functionality leading up to and through extreme events
- Developing and implementing technologies for rapid repair and restoration of critical infrastructure and critical services.

II. Progress in Fiscal Years 2005 and 2006

A. Reports by Agency

National Science Foundation

NSF Program Directors receive unsolicited proposals for research on a broad range of topics related to hazard mitigation. The programs range from atmospheric sciences programs that are concerned with physics-based topics related to formation of hurricanes and thunder storms to engineering programs focused on improving the performance of structures against wind loads, to social science programs devoted to societal response to natural disasters. Although these proposals are selected through the peer review process under programs intended to advance research in myriad areas and not just hurricanes and winds, the NSF portfolio of projects have collectively made important progress in each of four focus areas and many of the sub-areas defined above.

Understanding, Predicting and Forecasting:
Over the past two years, research in atmospheric sciences was begun to develop a better understanding of atmospheric dynamics of straight-line winds and to improve understanding of fundamental physics that control hurricane intensity; wave dynamics during hurricanes; collaborative research on the impact of externally and internally modulated convection on tropical cyclone evolution (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0514159). Understanding the hazard risk associated with extreme hurricane events is also being studied. Detecting synoptic-scale precursors of tornado outbreaks (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0527934) is the objective of one investigation. Another project is studying tornadic storms with Doppler Polarimetric Radar (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0532107).

Assessing the impacts of wind hazards
Shortly after Hurricane Katrina struck the Gulf States, 29 small grants were awarded for reconnaissance studies aimed at documenting the effects and preserving highly perishable data. Two of these studies on the performance of the levee system were expanded in scope to include engineering analyses of failed sections of the levees and proposed repair and replacement strategies. Development of instrumentation for the observational studies of the effects of atmospheric winds on structures near the ground was also undertaken. Another of these projects investigated large coastal bridge performance in a hurricane environment. Collection of perishable data on wood-frame residential structures in the wake of Hurricane Katrina was also undertaken. Studies were conducted to better understand the response of typical bridges to hurricanes and to assessing risk for long-span bridges. The determination of storm surge effects

on levees and the simulation of non-linear water waves during hurricanes were the subjects of other investigations. In order to better understand the impacts of hurricane disasters, construction material requirements for rebuilding New Orleans are being investigated and documented. Improving glass performance during wind storms and the modeling response of tall buildings to straight line winds are important for understanding the impacts to wind hazards.

Social science topics under investigation include evaluating preferences for rebuilding plans post-Katrina, assessing public health impacts of disasters, and decision making in displaced populations. In particular, one project is examining factors associated with compliance to Katrina mandatory hurricane evacuation orders in seven coastal Louisiana parishes.

Reducing Impacts of Wind Hazards
Resistance of existing wood roof structures and retrofit schemes is currently being studied to better understand how best to construct more resistant structures in the future. This type of damage accounts for a significant proportion of the damage caused by hurricanes and straight line winds each year. In addition, we also need to better understand the impact of hazard events on soils, infrastructure, and the submerged environment. A project entitled "The Effect of Katrina on Submerged Geotechnical Systems - Underwater Evaluation of Sediment-Structure-Storm Interaction" will provide important data on these important parts of the urban infrastructure. Another project that is vital to the energy supply is focusing on assessment of damage to underground tanks in New Orleans in the aftermath of Hurricane Katrina. Electric Utility Damage from Hurricane Katrina is also under investigation.

Preparedness and Enhancing Community Resilience
Instructional materials for K-12 are being developed to enhance preparedness among children. Also, information technologies are being developed to assist individuals in adapting to evacuation. Social networks are being studied to understand the role they might play in early warning strategies and subsequent compliance. Improving hurricane intensity forecasting is important to increase societal compliance and evacuation plans and orders, but the public must also be educated to understand risk and appropriate behavior to ensure their safety. Two studies are underway to better understand and improve evacuation procedures. Two projects have been funded for analyzing multi-organizational networks and their roles in hazard mitigation. Ten projects are underway that are investigating various tools that might be useful for building community resilience to wind hazards. One of these projects is examining how preferences for rebuilding plans are being made after Hurricane Katrina (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0554987). Another one is studying "The Parallel Strengths and Weaknesses of the Civil Society and the State: The Example of Katrina Survivors" (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0555113). "Cyberinfrastructure Preparedness for Emergency Response and Relief: Learning the lessons from Hurricane Katrina" is the focus of another investigation (http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0638561).

National Oceanic and Atmospheric Administration

NOAA activities and progress during the past two years can be divided into six categories: 1) development of plans, 2) provision of data of use for wind hazard reduction, 3) development of decision support tools and analyses of relevance to wind hazards, 4) understanding and predicting weather conditions producing wind damage, 5) creation of new facilities for improving our knowledge and prediction of wind hazards, and 6) education and outreach.

Development of plans:
NOAA developed a budget initiative for fiscal years 2009 to 2013 addressing the creation of resilient coastal communities of which resilience to wind hazards is a component. NIST and NOAA jointly developed a cooperative plan on Hazard-Resilient Communities. NOAA is represented on the U.S.-Japan Panel on Wind and Seismic Effects. This panel encourages exchange of information between the two countries and has initiated a joint project on bridge stay flutter. It proposes work on urban canopy wind modeling and verification and coupling of meteorological and computational fluid dynamic models to be used by wind structural engineers.

Providing data of use for wind hazard reduction:
During FY2004, several extreme turbulence (ET) probes[3, 4] were developed and successfully tested in actual hurricanes. These probes hold promise for very high spatial and temporal resolution measurements of winds on the immediate exterior of structures. In cooperation with NOAA, the Florida and South Carolina Sea Grant deployed portable towers measuring winds during Hurricanes Charley, Frances, Ivan, Katrina, and Rita. These data are useful for "nowcasts" of the winds and to duplicate wind tunnel measurements. The Shared Mobile Atmospheric Research and Teaching Radars (SMART-R), the result of a cooperative effort between the University of Oklahoma and NOAA, have been used in hurricane landfall deployments, and have been upgraded to deliver their data directly to forecast offices in real time[5, 6, 7, 8, 9]. The stepped frequency microwave radiometer is now deployed on both research and operation aircraft for much improved surface wind and vertical wind profiles over water within hurricanes and they are now used in NOAA's operational hurricane model and for real-time hurricane intensity analysis.

Decision support tools and analysis for wind hazards:
NOAA has been working with the state of Florida on a Public Hurricane Loss Projection Model to develop wind-dependent vulnerability functions for building retrofit guidance. The NOAA hurricane wind (H*WIND) analysis was used to validate this model. A stochastic model is being used to simulate 55,000 years of hurricane tracks for a wind demonstration project, conducted with NIST, to test wind and storm surge risk maps in a few selected coastal areas. The U.S. Army Corps of Engineers and NOAA completed a post-Hurricane Katrina, Charley, Frances, Ivan, and Jeanne 1-km resolution wind field analysis using the H*WIND product and data that were not available in real time. NOAA's National Hurricane Center introduced its new experimental wind-speed probability forecast in time for the 2006 hurricane season to map out several predicted wind-speed thresholds.

Understanding and predicting weather conditions producing wind damage:
NOAA continues to gather field data on hurricane inner core dynamics to better understand intensity changes. During the past two hurricane seasons, NOAA, with the Office of Naval Research, has been measuring the heat and momentum exchange between the atmosphere and

ocean within hurricanes to better parameterize this exchange in hurricane prediction models[10,11]. Preliminary testing of these new parameterizations in NOAA's operational hurricane model has improved hurricane intensity predictions. NOAA tested a new hurricane model during the 2006 hurricane season for operational application next season. It is coupled with an ocean model and has a nested and movable grid.

Creating new facilities for improving our knowledge and prediction of wind hazards:
The new National Weather Center in Norman, Oklahoma opened its doors during the summer of 2006. It consists of the South Research Campus of the University of Oklahoma, the NOAA Norman forecast office, the Storm Prediction Center, and the National Severe Storms Laboratory. This facility also features the Hazardous Weather Testbed, which performs research and development to improve prediction of hazardous winds. This year, Congress appropriated $2M to NOAA to promote collaboration among the University of Alabama/Huntsville's Earth System Science Center, NASA's Short-Term Prediction Research and Transition Center, NOAA's National Severe Storms Laboratory, and the Hazardous Weather Testbed. This collaboration will lead to improved prediction and monitoring of severe storms and their associated hazardous winds.

Education and outreach:

- NOAA's Louisiana Sea Grant program has developed fact sheets that include information on building codes, where and how to rebuild, and how to determine if a contractor is following state and federal regulations. It has been distributed to parishes and is available on the Internet. The program has also sponsored seminars on storm preparedness and has provided information on building codes and zoning practices.
- NOAA's Texas Sea Grant Program (Texas A&M) has been evaluating the Texas Mitigation Plan, which includes construction codes.
- The North Carolina Sea Grant (North Carolina State in collaboration with Oregon State) developed a break-away wall design for 125-mph winds and 1.5-ft waves, which has been adopted by the American Society of Civil Engineers.
- The South Carolina Sea Grant (Clemson) has developed low-cost methods for reducing storm damage, including strengthening roofs and shutters which have been adopted by a Sun City developer.
- There is now a "hazards house" in Charleston, SC, that helps educate the public on hazard-resilient building and retrofitting techniques, including those that mitigate wind effects.
- NOAA has prepared material for a documentary on how to stay safe in high winds, including how to improve housing construction to resist damage and the appropriate design for safe rooms. The documentary will be featured on the Discovery Channel.
- NOAA held its first Weather Partners open house in Norman, OK, for approximately 1000 visitors. Wind risk to structures was a prominent theme for discussion.
- NOAA organized a training session at the National Hurricane Conference on hurricanes and public health. During the session, a representative from the Institute of Building and Home Safety delivered a presentation on the resilience of

public health facilities against structural hazards. Key structural components included window strength, exterior cladding, roof edging, and vulnerability of roof type and roof mountings. The participants then critically evaluated a simulated hurricane scenario.

National Institute for Standards and Technology

NIST research over the past two years has focused on two areas: (1) to gain an understanding of wind hazards to the built environment; and (2) to develop predictive technologies and mitigation strategies to enhance disaster resilience to wind hazards.

Understanding Wind Hazards to the Built Environment

Extreme Wind Databases: To facilitate use of Automated Surface Observing Station (ASOS) wind data for structural engineering purposes, NIST developed procedures and software for (a) extraction of peak gust wind data from archived ASOS weather reports, (b) extraction of thunderstorm observations from archived weather reports, (c) classification of wind data as thunderstorm or non-thunderstorm to enable separate statistical analyses of these distinct types of winds, and (d) construction of data sets separated by specified minimum time intervals to ensure statistical independence. Estimates showed that, at these stations, thunderstorm wind speeds dominate the extreme wind climate to the extent that non-thunderstorm wind speeds can be disregarded in the analysis[12]. Using such records it is possible to obtain realistic probabilistic descriptions of the wind climate at stations where both types of wind occur. The software, data, and literature are available at www.nist.gov/wind.

Advanced Computational Tools for Determining Realistic Wind Loads in the Built Environment
NIST has developed software for analyzing wind effects on rigid, gable-roofed buildings, and flexible high-rise buildings using the database-assisted design methodology [13, 14, 15, 16, 17, 18, 19]. Database-Assisted Design (DAD) is a unified framework for analysis and design of buildings for wind loads that makes direct use of pressure-time histories measured at a large number of pressure taps on wind tunnel models. Local climatological information can be used in conjunction with the measured pressures to obtain estimates of peak wind effects with specified return periods for use in structural design. DAD offers more accurate estimation of peak wind effects than simplified procedures that are now used, which paves the way for more risk-consistent designs. The software, data, and literature are available at www.nist.gov/wind.

Methodologies for Predicting Ultimate Structural Capacities and Estimating Safety Margins
The design of many low-rise metal buildings in the U.S. is based on the ASCE 7-93 Standard and the use of Allowable Stress Design (ASD). NIST used the nonlinear database-assisted design technique to assess the degree of safety of a typical low-rise portal frame industrial structure designed in accordance with ASCE 7-93 and ASD as compared to the provisions of the ASCE 7-02 Standard. We have found that the frame being considered satisfies all ASCE 7-02 requirements with respect to wind loading but that its safety level is relatively low and could be improved substantially at very low cost[20].

Assessing the Performance of Structures in Wind Disasters
NOAA's National Weather Service implemented the enhanced Fujita Tornado Intensity Scale on an operational basis in February 2007. The enhanced Fujita scale is based upon observations by

a NIST researcher as part of a reconnaissance team deployed following the 1997 Jarrell, TX tornado and subsequent technical work performed by Texas Tech University with funding and technical oversight by NIST. The more realistic wind speeds associated with the enhanced scale will allow the use of routine standard provisions for the safe design of buildings under most tornadoes occurring in the U.S.

After Hurricane Katrina and Hurricane Rita, NIST assembled a team of experts to conduct a reconnaissance of the status of buildings, physical infrastructure, and residential structures in the New Orleans area, coastal Mississippi, and Southeast Texas. NIST documented its findings on the environmental conditions (e.g., wind speeds, storm surge elevations, and flooding) and on the performance of structures in the study areas in its final report issued in June 2006. The report includes 23 recommendations in three groups: 1) immediate impact on practice for rebuilding, 2) standards, codes, and practices, and 3) further study of specific structures or research and development[21].

Technical Basis for Improved Codes and Standards
Estimates of the World Trade Center (WTC) towers' response to wind by two North American wind engineering laboratories differed from each other by almost 50 percent. A recent NIST investigation indicated that those differences reflected discrepancies between the respective estimates of the wind speeds and the respective modeling of directional interaction between wind speeds and aerodynamic/dynamic response of the building[22, 23].

NIST analyzed the role of risk-consistent probabilistic definitions of peak wind effects in developing safety margins for inclusion in codes and standards.

U.S.-Japan Panel on Wind and Seismic Effects
NIST chairs the US-Japan Joint Panel on Wind and Seismic Effects and NIST staff actively participates in the Panel and its wind engineering task committee. The Panel provides an effective mechanism for the exchange of technical data and information, the exchange of researchers, and the coordination of joint research on topics of mutual interest to the US and Japan.

Federal Emergency Management Agency

FEMA activities and progress during the past two years can be organized in the following categories: 1) risk assessment; 2) windstorm-related data collection and analysis; 3) public outreach; 4) implementation of mitigation measures consistent with the Agency's all-hazards approach; and 5) hurricane program coordination.

Risk Assessment
Hazards US – Multi-Hazard, or HAZUS-MH, is a risk assessment program developed by FEMA for analyzing potential losses from floods, hurricane winds and earthquakes. In HAZUS-MH, current scientific and engineering knowledge is coupled with the latest GIS technology to produce estimates of hazard-related damage before, or after, a disaster. HAZUS-MH estimates include: physical damage to buildings and infrastructure; economic loss, including lost jobs, business interruptions, repair and reconstruction costs; and social impacts, including shelter requirements, displaced households, and population exposed to the disaster. HAZUS-MH MR2, the second maintenance release of the HAZUS-MH software program, became available from

FEMA in April 2006. HAZUS-MH MR2 produces loss estimates based on state-of-the-art scientific and engineering knowledge and software architecture. These estimates are essential for decision-making at all levels of government, and are a basis for developing mitigation plans and policies, emergency preparedness, scenarios used to conduct exercises, and response and recovery planning.

Windstorm-related data collection and analysis
FEMA conducts Mitigation Assessment Team (MAT) studies of building performance after hurricanes. During the year since the catastrophic devastation of Hurricane Katrina, the Mitigation Division has made significant strides in helping the residents of the Gulf Coast rebuild by providing unprecedented levels of support and resources. After Katrina, FEMA deployed a MAT to evaluate and assess damage from that storm and provide observations on the performance of structures impacted by flood and wind forces along with recommendations for improved disaster resistant construction. The team released a comprehensive report earlier this year. Key findings from the report include: 1) Lack of adequate building codes in the affected states greatly compounded the effect of Hurricane Katrina on building performance; 2) Storm surge and wave crest elevations from Hurricane Katrina exceeded the mapped base flood elevations in many coastal areas of Alabama, Louisiana, and Mississippi and flood damage was severe in these areas; and 3) Hurricane Katrina was less than a design-level storm for wind in most areas; however, wind damage was widespread and was severe in some areas. Buildings that experienced substantial structural damage typically were built before wind effects were adequately considered in building design and construction.

Implementation of mitigation measures consistent with the Agency's all-hazards approach
As part of the MAT effort, the team developed first-of- its- kind construction guidance that provides coastal residents with engineering guidance and complete foundation solutions for rebuilding in the Gulf. In great demand, the MAT experts have delivered nearly 40 briefings and presentations on Katrina to local, regional, state and national audiences. By using better building practices now, Gulf Coast communities will be strengthened and more resilient when the next hazardous storm occurs. *FEMA 550 Residential Construction for the Gulf Coast: Building on Strong and Safe Foundations* provides homeowners, builders and design professionals with prescriptive, pre-engineered foundation solutions, cost information and guidance on choosing and constructing disaster-resistant foundations. Another publication receiving widespread dissemination and usage is FEMA 499 Homebuilders Guide to Coastal Construction - Technical Fact Sheet Series. This publication is a series of 31 colorful and graphic fact sheets that detail critical components of successful coastal building construction. To date, over 20,000 copies have been ordered and provided.

Public Outreach
The FEMA web site, www.fema.gov, serves as the nation's portal to emergency and disaster information. During the month that followed Hurricane Katrina's landfall along the Gulf Coast, more than 14 million visits and 400 million hits were logged on the Web site.

Hurricane Program Coordination
FEMA and NOAA worked together to improve evacuation planning for hurricanes. Improved hurricane intensity predictions resulting from NOAA's research are used to improve evacuation

decision-making and limit evacuations to only those who absolutely need to evacuate, thereby reducing congestion on the highways.

Over the past two years, FEMA has worked in coordination with NOAA to improve planning based on improved data and Sea, Lake and Overland Surges from Hurricanes (SLOSH) modeling parameters. The NOAA SLOSH hurricane storm surge model is used nationwide to predict the storm surge magnitude for all categories of storms along the coastal regions. Since Hurricane Isabel, NOAA has conducted reviews and examinations of the SLOSH data and has made adjustments to the model for future real time predictions.

Federal Highway Administration[21, 23]

Understanding, Predicting and Forecasting Wind Hazards
The FHWA Office of Infrastructure R&D continuously monitors winds at the sites of three major long-span, cable-supported bridges to establish and characterize site-specific wind conditions and the responses of the bridges. All sites are relatively near the coastline with one in Louisiana, another in Delaware, and the third in Maine. The engineering data collected at these sites provides valuable input into design of new structures.

Assessing the Impact of Wind Hazards
The FHWA Office of Infrastructure R&D has continuously monitored the wind environment and detailed response of three major long-span, cable-supported bridge structures to evaluate their wind performance and wind resistance. The Computational Fluid Dynamics (CFD) model UABRIM is being enhanced by implementation of unstructured and adaptive grids for use in simulating the interaction between wind and structures such as large bridges. Tests have been completed in our small wind tunnel using evolving Particle Image Velocimetry (PIV) technology to study wind flow fields around and compute wind forces on several representative bridge deck sections.

The FHWA Office of Operations continued activities under the Road Weather Management Program, which seeks to develop and promote effective tools for observing and predicting the impacts of weather on the roads, and to alleviate these weather impacts. As part of the program, the Clarus Initiative has continued to conduct activities to develop and demonstrate an integrated surface transportation weather observing, forecasting and data management system, and to establish a partnership to create a Nationwide Surface Transportation Weather Observing and Forecasting System. The Initiative Coordinating Committee (ICC) held its annual meeting in August 2006.

Reducing the Impact of Wind Hazards
The FHWA Office of Infrastructure R&D has initiated research to prepare a synthesis report on Wind Load Criteria for Cable Supported Structures. Complementary research has also been initiated to prepare a synthesis report on User Comfort and Serviceability Criteria for Wind Loading. Research has continued on the issue of wind- and wind/rain-induced vibration of bridge stay cables. A draft guidelines document is under development for the aerodynamic design of bridge stay cables.

Preparedness and Enhancing Community Resilience
The FHWA Office of Infrastructure R&D, together with the Missouri Department of Transportation, organized and held the 2nd National Workshop on Wind-Induced Vibration of Cable-Stayed Bridges in April 2006. This workshop served to disseminate the latest information on the mitigation of wind-induced vibrations to state bridge engineers and design consultants.

B. Table of Agency Progress (FY2005 and FY2006) in the Four Implementation Themes

	NIST	NSF	NOAA	FEMA	FHWA
1. Understanding, Predicting and Forecasting					
Enhancing knowledge, information and data on severe winds	Developed procedures and software for extraction of peak gust wind data and thunderstorm observations from archived ASOS weather reports, classification of wind data as thunderstorm or non-thunderstorm, and construction of data sets separated by specified minimum time intervals to ensure statistical independence.	Better understanding of atmospheric dynamics of straight-line winds; modeling, and measuring of error effects	Developed extreme turbulence probe. Deployed portable towers in hurricanes at landfall. Deployed stepped frequency microwave radiometer. Improvements in mobile radars. These instruments provide much improved and robust wind measurements near the ground and, therefore, improved understanding of the forces experienced by structures in actual hurricanes.	Conducted Mitigation Assessment Team (MAT) evaluations following Hurricanes Charley and Ivan in 2004 and Hurricane Katrina in 2005	Monitor/Characterize wind conditions at 3 bridge sites
Improving prediction of hazardous wind events	Developed procedure for statistical estimation of extreme wind speeds in mixed non-thunderstorm/ thunderstorm wind climates.	Tornado genesis and tornadic vortex structure	Modeled hurricane inner core dynamics. Improved air-sea exchange parameterizations. Tested improved hurricane model for operational use. Established new National Weather Center in Norman, Oklahoma to improve research and development related to the prediction of hazardous winds.		
Understanding and quantifying wind loading	Developed methods for utilizing database-assisted design for rigid and flexible buildings and implemented the methods in software. The database assisted design method uses pressure time histories measured at a large number of pressure taps on wind tunnel models. Evaluated the procedure for estimating extreme wind effects by the directional sector-by-sector approach.	Improved understanding of fundamental physics that control hurricane intensity; wave dynamics during hurricanes; effects of convection on cyclones		Conducted MAT evaluations (see above) and worked with the International Code Council (ICC) to develop a Wind Shelter Standard	
Understanding the perception of wind hazard risk		Anticipation of extreme hurricane winds		Conducted MAT evaluations (see above) and worked with the International Code Council (ICC) to develop a Wind Shelter Standard	

Mapping wind hazards			Provided surface wind analysis for Florida building retrofit guidance. Provided hurricane track statistics for wind and storm surge risk maps. Assisted Army Corps of Engineers with high resolution wind maps of recent significant hurricanes.		
2. Assessing Impacts					
Investigating wind resistance of buildings, structures and critical infrastructure	NOAA's NWS implemented the enhanced Fujita Tornado Intensity Scale operationally in February 2007. The enhanced Fujita scale is based upon observations by a NIST researcher following the 1997 Jarrell, TX tornado and technical work performed by Texas Tech University with funding and technical oversight by NIST. NIST led a reconnaissance of the performance of buildings, physical infrastructure, and residential structures affected by Hurricanes Katrina and Rita.	Development of instrumentation for the observational study of atmospheric winds; Bridge response to hurricanes; documentation of wind effects; workshop on wind effects; performance of tanks and industrial facilities during Katrina (2 projects); performance of underground structures during Katrina; response of submerged geotechnical systems and buried infrastructure (3 projects); reconnaissance studies (2 projects)		Conducted MAT evaluations (see above)	Measure wind/structure interaction of 3 bridges
Developing improved tools for component- and structure-level simulation and numerical modeling of wind effects	Developed wind engineering software, data, and literature, which is described at www.nist.gov/wind.	Improving glass performance; response of tall buildings to straight line winds; response and repair of levee systems for Katrina			Enhance CFD bridge model Perform wind/bridge flow visualization tests using PIV in wind tunnel
Developing improved tools for loss assessment of wind hazards		Assessing risk for long-span bridges; determination of storm surge on levees; simulation of non-linear water waves during hurricanes; construction material requirements for rebuilding New Orleans	Developed low-cost methods for reducing storm damage, including strengthening roofs and shutters, from NOAA Sea Grant.	Completed development and release of HAZUS-MH MR 1 and MR 2 updates for Hurricane Winds and methodology for Hurricane Storm Surge Model	Continue road weather management program
Assessing social costs		Evaluating performance for rebuilding plans post-Katrina; assessing public health impacts; decision making in displaced populations; Electric utility damage from Katrina; impact of Katrina and storm surge on human and built environment		Completed a major study through the National Institute of Building Sciences (NIBS) on the Benefits of mitigation which determined a 4:1 return on mitigation investment	

3. Reducing Impacts					
Assessing and communicating risk		Improving hurricane intensity forecasting	Introduction of experimental wind speed probability product.	Completed HAZUS-MH MR 1 and MR 2 releases; Ongoing Hurricane Evacuation Studies and Planning; conducted over 50 briefings on the results of the Hurricane Katrina MAT	
Developing prototype structural requirements		Resistance of 'wood roof' structures		Participated in standards development committees: ASCE 7 Wind Loads Task Committee; the ICC Wind Shelter Standard; and the NFPA Manufactured Housing Foundations Standard	Initiate research on wind load criteria; Initiate research on comfort and serviceability criteria
Demonstration, education, training and outreach on improved codes and building guidelines	Participated in the ASCE 7 Standard Committee on Wind Loads; trained future wind engineers (post-doctoral researchers, graduate and under-graduate students).			Conducted over 50 Hurricane Katrina MAT briefings; HAZUS Hurricane Module training to over 500 people; numerous presentations and speeches at conferences	Draft design guidelines for stay cables
Guidance on retrofitting				Developing an electronic tool assessment and retrofit for wind, flood and earthquake for residences	
Innovative technologies			Developed breakaway wall design for 125 mph winds and 1.5 ft waves from NOAA Sea Grant.		
Land use measures and cost effective construction practices				Ongoing evacuation planning studies with the US Corps of Engineers and coastal States in hurricane-prone regions	
4. Preparedness and Enhancing Community Resilience					
Developing tools for community preparedness to wind hazards		Developing tools for preparedness for hurricanes and wind storms (8 projects); response of Texas school systems to Katrina; emergency preparedness planning and on-line evacuation of large buildings	"Hazards house" in Charleston, SC, developed by NOAA Sea Grant.	Ongoing efforts to improve and develop tools for effective State and local evacuation and sheltering plans	
K-12 and college education needs	Trained future wind engineers (post-doctoral researchers, graduate and undergraduate students).	Development of instructional materials on disaster preparedness. Tracking Katrina: algebra project instructional materials using stories by displaced New Orleans students		Delivered hurricane mitigation training to University professors thru the MRDSI Summer Institute and thru presentations to conferences where educators are present	

General public awareness and outreach	Conducted initial series of briefings to state and local building officials and emergency managers on the findings and recommendations of the Hurricane Katrina and Hurricane Rita reconnaissance.	Development of social networks for early warning	Developed fact sheets on building codes, rebuilding, and contractor issues from NOAA Sea Grant to Louisiana. Held session at National Hurricane Conference on public health facility resilience to winds. Prepared material for Discovery Channel program on wind safety and Weather Partners open house.	Delivered hurricane mitigation training to University professors thru the MRDSI Summer Institute and they presented issues to conferences where educators are present.	
Evacuation Planning		Study on adapting to evacuation: information technology. Evacuation studies (2 projects)		Ongoing activity and improvements information, products, and tools for effective State and local hurricane evacuation and sheltering plans	
Enhancing disaster resistance of Building Codes and Standards	Determined that differences in estimates of the World Trade Center (WTC) towers' response to wind by two North American wind engineering laboratories were due to discrepancies between the respective estimates of the wind speeds and the respective modeling of directional interaction between wind speeds and the response of the building. Analyzed the role of risk-consistent probabilistic definitions of peak wind effects in developing safety margins for inclusion in codes and standards.	Code analysis and studies of enforcement		Participated in ASCE 7 Wind Loads Task Committee; ICC Wind Shelter Design Standard development; Proposed successful code changes to improve wind resistance of national model buildings codes	Held workshop on wind-induced cable vibration
Building public and private partnerships				Working cooperatively with US Dept of Housing and Urban Development (HUD), American Society of Civil Engineers (ASCE), US Corps of Engineers and others	
Conducting emergency response exercises		Analyzing emergent multi-organizational networks (2 projects)		Conducted major catastrophic planning activity for a hurricane exercise in New Orleans and began planning for a Cat 5 Miami hurricane exercise.	

III. Summary

One of the primary goals of the National Windstorm Impact Reduction Program is to increase the effectiveness of existing program efforts through better coordination among agencies. Improved coordination can frequently produce improvements in existing research with little or no additional expense. During fiscal years 2005 and 2006, NWIRP agencies improved communications and collaborations among Federal programs in the following ways:

- Enhanced knowledge, collected data and shared information on severe winds
- Investigated wind resistance of buildings and structures (in particular, bridge structures)
- Developed improved tools for assessment of losses from wind hazards
- Increased general public awareness and outreach on specific wind-related topics
- Assisted in the development of evacuation planning and guidance

In addition, improved communication revealed several research areas in the Windstorm Impact Reduction Implementation Plan that deserve further attention or development:

- Understanding the perception of wind hazard risk
- Mapping wind hazards
- Assessing and communicating risk
- Developing prototype structural requirements
- Guidance on retrofitting
- Innovative technologies for assessment and mitigation
- Land use measures and cost effective construction practices
- Building public and private partnerships
- Conducting emergency response exercises

These areas of research will be re-examined during subsequent discussions and planning, and will be factored into subsequent prioritization of research needs.

In some sectors of wind research, the delivery of existing research results to users would provide high value for resources invested, and this will be emphasized during the next year. Interagency coordination is improving through the work of the Interagency Working Group. Strong interagency coordination and collaboration allows for more efficient use and leveraging of existing resources. Under the auspices of the National Science and Technology Council, the NWIRP Interagency Working Group will continue to perform gap analyses, which will provide more detailed guidance on where resources are needed to accomplish the goals of the implementation plan.

One of the focusing events of the historic 2005 U.S. hurricane season was the landfall and resulting unprecedented disaster caused by Hurricane Katrina. Although dozens of Federal agencies responded to the massive damage caused by this hurricane and the subsequent breach of the New Orleans levees, the science agencies of the National Windstorm Impact Reduction Program used this destructive storm as an opportunity to expand our knowledge of hurricanes and the effects of high winds on buildings, bridges, and natural systems. The following list is a partial summary of science activities in the NWIRP agencies, some conducted individually, some conducted collaboratively:

NIST

- Led a reconnaissance of the performance of buildings, physical infrastructure, and residential structures affected by Hurricanes Katrina and Rita.
- Conducted initial series of briefings to state and local building officials and emergency managers on the findings and recommendations of the Hurricane Katrina and Hurricane Rita reconnaissance.

NSF

- Development of instrumentation for the observational study of atmospheric winds; Bridge response to hurricanes; documentation of wind effects; workshop on wind effects; performance of tanks and industrial facilities during Katrina (2 projects); performance of underground structures during Katrina; response of submerged geotechnical systems and buried infrastructure (3 projects) reconnaissance studies (12 projects)
- Improving glass performance; response of tall buildings to straight line winds, response and repair of levee systems for Katrina
- Assessing risk for long-span bridges; determination of storm surge on levees; simulation of non-linear water waves during hurricanes; construction material requirements for rebuilding New Orleans
- Evaluating preferences for rebuilding plans post-Katrina; assessing public health impacts; decision making in displaced populations; Electric utility damage from Katrina; impact of Katrina and storm surge on human and built environment
- Developing tools for preparedness for hurricanes and wind storms (8 projects); response of Texas school systems to Katrina; emergency preparedness planning and on-line evacuation of large buildings;
- Development of instructional materials on disaster preparedness; Tracking Katrina: algebra project instructional materials using stories by displaced New Orleans students

NOAA

Although NOAA's role in Katrina was largely operational, many of its activities informed subsequent scientific investigations by other agencies.

- NOAA National Climatic Data Center provided storm meteorological data (rain, wind, and pressure) and social and economic impact data.
- Aircraft missions into Katrina, satellite images from various sources, tropical cyclone surface wind field analyses, radar data from aircraft and land-based stations.
- National Ocean Service provided water levels for Hurricane Katrina, including observed versus predicted water levels.
- The U.S. Army Corps of Engineers and NOAA completed a post-Hurricane Katrina, Charley, Frances, Ivan, and Jeanne 1-km resolution wind field analysis using the H*WIND product and data that were not available in real time.

- NOAA's Louisiana Sea Grant program has developed fact sheets that include information on building codes, where and how to rebuild, and how to determine if a contractor is following state and federal regulations. It has been distributed to parishes and is available on the Internet. The program has also sponsored seminars on storm preparedness and has provided information on building codes and zoning practices.

FEMA

- Conducted Mitigation Assessment Team (MAT) evaluations following Hurricanes Charlie and Ivan in 2004 and Hurricane Katrina in 2005
- Completed HAZUS-MH MR 1 and MR 2 releases; Ongoing Hurricane Evacuation Studies and Planning; conducted over 50 briefings on the results of the Hurricane Katrina MAT
- HAZUS Hurricane Module training to over 500 people; numerous presentations and speeches at conferences

Although the tragic toll of human life and property damage resulting from Hurricane Katrina and associated events is indisputable, it reveals the importance of collecting perishable scientific data in a timely manner. Expert observations and data collection during and immediately after such an event informs the research that is intended to reduce our vulnerability to wind-related hazards. The National Windstorm Impact Reduction Program agencies responded quickly and well to this scientific opportunity.

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Attachment 3

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

June 23, 2008

The Honorable Bart Gordon
Chairman
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Thank you for your letter inquiring about the Administration's activities regarding the National Windstorm Impact Reduction Program (NWIRP). I agree that wind storms present a serious hazard to communities, with significant loss of life and property.

Under the provisions of the statute, P.L. 108-360, the Program interagency working group (IWG) was required to produce an implementation plan (and biennial update) for achieving the objectives of the Program and deliver the plan to Congress in April 2006 The most recent update was submitted to Congress in 2007 and covers fiscal years 2005 and 2006. The next biennial report will be submitted in the fall of 2008 or spring of 2009. This letter provides a brief update but is not intended to substitute for the required biennial report.

In this Administration, the National Science and Technology Council (NSTC) plays an important coordinating role for Federal agencies that deal with natural hazards and disasters. The Federal agencies take, to the extent practicable, an "all hazards" approach to dealing with natural threats and disasters. This approach is necessary because many of the dangers of natural hazards are common to several different hazard types. It is impractical, and in some cases impossible, to separate the causes and impacts of these important events.

Under the NSTC Subcommittee on Disaster Reduction (SDR), the following natural hazards are have been addressed: coastal inundation, drought, earthquake, flood, heat wave, human and ecosystem health, hurricane, landslide and debris flow, space weather, technological disasters (industrial accidents), tornado, tsunami, volcano, wildland fire, and winter storm. Wind related hazards are included under hurricane, tornado, and winter storm, and wind hazards are viewed in the context of all hazards. The NWIRP IWG functions under this Subcommittee.

In June of 2005, the SDR published its report, "Grand Challenges for Disaster Reduction" that identified a set of overarching challenges that apply to all hazard types. They include:

1. Provide hazard and disaster information where and when it is needed.
2. Understand the natural processes that produce hazards.
3. Develop hazard mitigation strategies and technologies.
4. Recognize and reduce vulnerability of interdependent critical infrastructure.
5. Assess disaster resilience using standard methods.
6. Promote risk-wise behavior.

These six grand challenges are intended to guide the research investments in Federal agencies for all hazard types. In addition, the SDR subsequently published a set of hazard specific implementation plans for each of the hazard types in order to specify the research and development issues required within the Federal agencies to address the grand challenges. The original grand challenge document and implementation plans are available on the OSTP web site: http://www.ostp.gov/cs/nstc/documents_reports. We strongly believe that an integrated approach to understanding, mitigating, and preparing for all hazards is the best way forward.

In that spirit, windstorm impacts are fully integrated into this planning and coordination process. Agencies are in the best position to weigh the needs for research related to the various hazards and to adjust their budget requests appropriately to address the integrated approach to reducing the threat of natural hazards. The principle agencies under NWIRP (FEMA, NOAA, NSF, and NIST) are balancing a portfolio of research in which it is sometimes difficult to assign a particular research investment to a specific hazard.

Furthermore, the Subcommittee on Disaster Reduction, in its commitment to engaging non-federal partners and stakeholders, works with the National Academy of Science to sponsor the Disaster Roundtable, which periodically brings together experts from agencies, industry, academia, and non-governmental organizations to address issues surrounding natural hazards and disasters. Recent examples of Roundtables focus areas are:

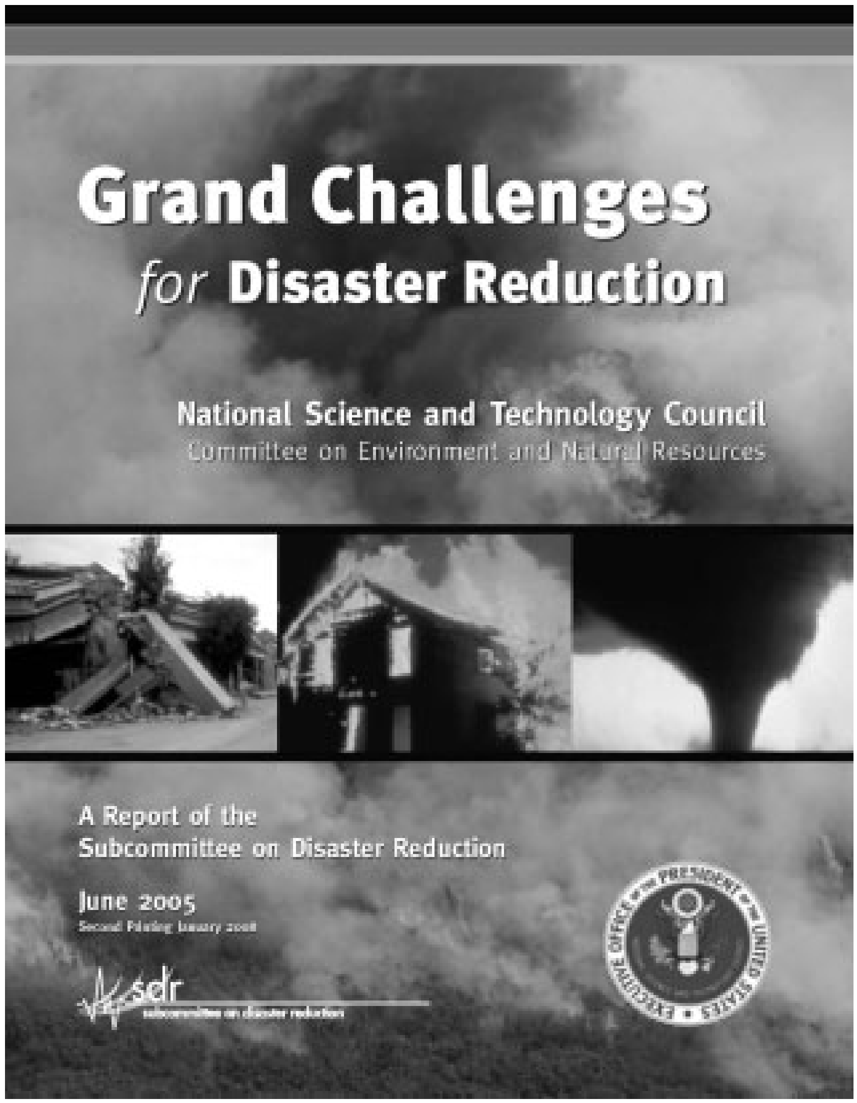
- Disaster Risk Management in an Age of Climate Change
- Protecting Lives and Property at our Coastlines
- Rebuilding for Health, Sustainability, and Disaster Preparedness in the Gulf Coast Region
- Community Disaster Resilience
- Law, Science, and Disaster
- Lessons Learned Between Hurricanes: From Hugo to Charley, Frances, Ivan, and Jean
- Creating a Disaster Resilient America: Grand Challenges in Science and Technology
- Hazards Watch: Reducing Disaster Losses Through Improved Earth Observations
- Alerting America: Effective Risk Communication
- From Climate to Weather: Impacts on Society and Economy
- Sea Level Rise and Coastal Disasters

A well planned and coordinated "all hazards" approach to natural disasters, placing wind hazards in the context of other natural hazards, is the most effective way to establish research funding priorities. This approach ensures that windstorm impacts will be appropriately prioritized and funded.

Sincerely,

John H. Marburger, III
Director

Attachment 4



EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20502

June 2005

Dear Colleague:

Every year, natural and technological hazards in the United States cost an estimated $1 billion per week in the form of lives lost and public and private properties destroyed. In 2004 alone, more than 60 major disasters, including floods, hurricanes, earthquakes, tornadoes, and wildfires, struck the United States. Reducing these losses requires collaboration at all levels and a coordinated, interagency approach. The Subcommittee on Disaster Reduction (SDR), an element of the President's National Science and Technology Council (NSTC), represents the expertise of more than 20 Federal agencies with disaster reduction missions and facilitates our national strategies for effective use of science and technology to reduce disasters.

To develop a ten-year strategy for disaster reduction through science and technology, the members of the SDR collaborated with scientists and engineers worldwide to identify a suite of Grand Challenges for disaster reduction. This document presents six Grand Challenges for disaster reduction and provides a framework for prioritizing the related Federal investments in science and technology. Addressing these Grand Challenges will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of hazards and enhancing the safety and economic well-being of every individual and community.

Sincerely,

John H. Marburger, III
Director, Office of Science and Technology Policy
Science Advisor to the President

Grand Challenges *for* Disaster Reduction

National Science and Technology Council
Committee on Environment and Natural Resources

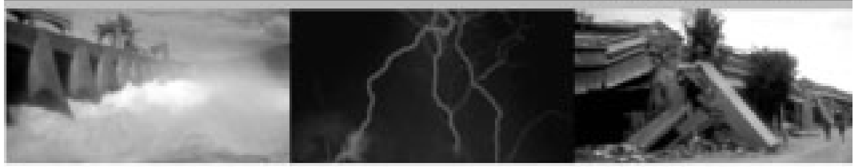
A Report of the Subcommittee on Disaster Reduction

June 2005

Second Printing January 2008

sdr
subcommittee on disaster reduction

Contents



Executive Summary

Despite significant progress in the application of science and technology to disaster* reduction, communities are still challenged by disaster preparation, response, and recovery. We have reduced the number of lives lost each year to natural disasters, but the costs of major disasters continue to rise. A primary focus on response and recovery is an impractical and inefficient strategy for dealing with these ongoing threats. Instead, communities must break the cycle of destruction and recovery by enhancing their disaster resilience.

The Subcommittee on Disaster Reduction identified four key characteristics of disaster-resilient communities:

- Relevant hazards are recognized and understood.
- Communities at risk know when a hazard event is imminent.
- Individuals at risk are safe from hazards in their homes and places of work.
- Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed.

High-priority science and technology investments, coupled with sound decision-making at all levels, will dramatically enhance community resilience and thus reduce vulnerability. In support of this goal, the following six Grand Challenges provide a framework for sustained Federal investment in science and technology related to disaster reduction:

Grand Challenge #1—Provide hazard and disaster information where and when it is needed. To identify and anticipate the hazards that threaten communities, a mechanism for real-time data collection and interpretation must be readily available to and usable by scientists, emergency managers, first responders, citizens, and policy makers. Developing and improving observation tools is essential to provide pertinent, comprehensive, and timely information for planning and response.

Grand Challenge #2—Understand the natural processes that produce hazards. To improve forecasting and predictions, scientists and engineers must continue to pursue basic research on the natural processes that produce hazards and understand how and when natural processes become hazardous. New data must be collected and incorporated into advanced and validated models that support an improved understanding of underlying natural system processes and enhance assessment of the impacts.

Grand Challenge #3—Develop hazard mitigation strategies and technologies. To prevent or reduce damage from natural hazards, scientists must invent—and communities must implement—affordable and effective hazard mitigation strategies, including land-use planning and zoning laws that recognize the risks of natural hazards. In addition, technologies such as disaster-resilient design and materials and smart structures that respond to changing conditions must be used for development in hazardous areas.

* Note: In this document, the terms disasters and hazards encompass events with both natural and technological origins.

By designing and building structures and infrastructures that are inherently hazard resilient, communities can greatly reduce their vulnerability.

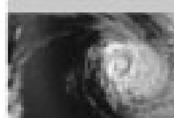
Grand Challenge #4—Recognize and reduce vulnerability of interdependent critical infrastructure. Protecting critical infrastructure systems, or lifelines, is essential to developing disaster-resilient communities. To be successful, scientists and communities must identify and address the interdependencies of these lifelines at a systems level (e.g., communications, electricity, financial, gas, sewage, transportation, and water). Using integrated models of interdependent systems, additional vulnerabilities can be identified and then addressed. Protecting critical infrastructure provides a solid foundation from which the community can respond to hazards rapidly and effectively.

Grand Challenge #5—Assess disaster resilience using standard methods. Federal agencies must work with universities, local governments, and the private sector to identify effective standards and metrics for assessing disaster resilience. With consistent factors and regularly updated metrics, communities will be able to maintain report cards that accurately assess the community's level of disaster resilience. This, in turn, will support comparability among communities and provide a context for action to further reduce vulnerability. Validated models, standards, and metrics are needed for estimating cumulative losses, projecting the impact of changes in technology and policies, and monitoring the overall estimated economic loss avoidance of planned actions.

Grand Challenge #6—Promote risk-wise behavior. Develop and apply principles of economics and human behavior to enhance communications, trust, and understanding within the community to promote "risk-wise" behavior. To be effective, hazard information (e.g., forecasts and warnings) must be communicated to a population that understands and trusts the messages. The at-risk population must then respond appropriately to the information. Significant progress is being made, but this is an ongoing challenge that can only be met by effectively leveraging the findings from social science research.

Advances in science and technology alone cannot fully protect the Nation from all hazards. In support of these Grand Challenges, key research and major technology investments must be linked to effective "risk-wise" policy decisions at all levels. Change must occur at both the policy level and in the societal perception of risk so that adoption and adaptation keep pace with advances in science and technology. A sustained emphasis on risk mitigation and public/private partnerships is essential throughout all aspects and at all levels of the community. Within this integrated planning context, improved coordination of sustained Federal science and technology investment to address the Grand Challenges for Disaster Reduction will enhance disaster resilience and national safety.

Disaster Profile: Hurricane



Since 1900, hurricanes and tropical storms making landfall on the U.S. Gulf Coast have caused more than 9,000 deaths and more than $100 billion in damages (adjusted to 2004 dollars) to homes and property.[1] In 2003, a single storm, Hurricane Isabel, caused over $4 billion in damages on the Atlantic Coast and resulted in the loss of 47 lives.[2] In 2004, a series of major storms struck the Atlantic and Gulf Coasts of the United States, affecting 15 states and costing billions of dollars in damages.

To protect against this hazard, atmospheric conditions must be continually monitored to detect the storm in the early stages and apply models to predict its motion and intensity. Once the storm is detected, everyone must be informed quickly and provided with understandable, actionable information, such as evacuation plans and shelter locations. Individuals must be aware of the risk and know how to act. Before the storm, knowledge of local weather patterns and micrometeorological effects will be applied. This knowledge should be incorporated into building codes and the choice of building materials, as well as community design, to mitigate against property damages and disruption to essential utilities and services.

Introduction: What's at Stake?

Each year, natural and technological disasters cause an estimated $52 billion in damages in the United States in terms of lives lost, disruption of commerce, properties destroyed, and the costs of mobilizing emergency response personnel and equipment.[1] As the costs continue to rise, we must move from response and recovery to proactively identifying hazards that pose threats and taking action to reduce the potential impacts.

To reduce future escalation of these costs, the United States invests significant Federal funds in disaster-related science and technology to reduce the loss of life and property damage from hazards. Despite this progress, however, the United States still faces enormous losses each year from hazards.

Hazards will always exist. Whether they become disasters depends upon our disaster resilience—our capacity to prepare, mitigate, respond, and recover. This report outlines key opportunities for scientific and technological advances that will enhance disaster resilience and thus improve the Nation's ability to face disasters.

Hazards in the United States

Drought. Drought is a complex and widespread natural hazard, affecting more people in the United States than any other natural hazard and accumulating average annual estimated losses between $6 and $8 billion. The magnitude and complexity of drought hazards have increased in association with growing population, population shifts to drier climates, urbanization, and changes in land and water use.[2]

Earthquakes. Each year, the United States experiences thousands of earthquakes and, on average, seven earthquakes per year have a magnitude of 6.0 or greater, enough to cause serious damage.[3] Although major advances have been achieved in understanding and mitigating earthquake hazards, 75 million Americans in 39 states face significant risk from earthquakes.[4]

Floods. Floods are the most frequent natural disaster; one in three Federal disaster declarations is related to flooding.[5] An increase in population and development in flood-prone areas, along with an increase in heavy rain events during the past fifty years, have gradually increased flood-related economic losses.[6] Property damages from flooding average $7 billion a year.[7]

Public Health/Environmental Disaster. Public health and environmental disasters may arise from natural events or human-caused releases of hazardous materials. The hazard may be primary or it may be the result of a previously existing hazard. Disease outbreaks, such as Severe Acute Respiratory Syndrome (SARS), clearly show the importance of public health monitoring, emergency communication, and international cooperation.

Mount Saint Helens, November 4, 2004, USGS photograph taken by Jon Valance and Matt Logan

Diseases spread by common vectors, such as West Nile Virus, reinforce the need for a public health education program in every community.

Severe Weather. Due to changes in population demographics and more complex weather-sensitive infrastructure, Americans today are more vulnerable than ever before to severe weather events caused by tornadoes, hurricanes, severe storms, heat waves, and winter weather. For example, during May 2003, the United States was hit with 563 tornadoes, breaking the previously existing monthly record of 399 tornadoes established in 1992. In many cases, communities underestimate the dangers of extreme weather events, as was the case in 1995, when a heat wave in Chicago killed 739 people. Over the past 50 years coastal population growth has quadrupled; more than 49 million people now reside along hurricane prone coastlines in the United States.

Technological. Technological hazards involve the release of hazardous substances—chemicals, toxic substances, gasoline and oil, nuclear and radiological material, flammable and explosive materials, in the form of gases, liquids, or solids—that impact human health and safety, the environment, and/or the local economy. Such hazards exist during production, storage, transportation, use and disposal and can adversely impact oceans, groundwater systems, streams, rivers, agricultural fields, and even urban areas.

Volcano. The United States is among the most volcanically active nations in the world with nearly 20 active or potentially active volcanoes. During the 20th century, volcanic eruptions in Washington, Oregon, California, Alaska, and Hawaii devastated thousands of square miles and caused substantial economic and societal disruptions and loss of life. Even with improved abilities to identify hazardous areas and predict eruptions, increasing numbers of people face volcanic hazards as a potential danger.

Wildland Fire. Despite national progress in reducing wildland fire hazards, tens of millions of acres of American wildlands and thousands of communities at the wildland/urban interface still are at risk of catastrophic wildland fire. During the winter rainy season, disastrous debris flows often follow. The extreme fire season of 2000 saw the largest areas burned by wildland fires in the United States since the 1960s. From 1999 to 2002, the average area burned by wildland fire was 6.1 million acres (24,685.82 kilometers²), with an estimated cost of $1.1 billion for wildland fire suppression.

Grand Challenges: A Framework for Action

In partnership with local, state, Federal, and international experts, the members of the the Subcommittee on Disaster Reduction identified four key characteristics for disaster-resilient communities:

- Relevant hazards are recognized and understood.
- Communities at risk know when a hazard event is imminent.
- Individuals at risk are safe from hazards in their homes and places of work.
- Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed.

If addressed, the critical problems in science and technology outlined here can help achieve these characteristics in every community. These Grand Challenges require sustained Federal investment in research, education, communication and the effective application of technology. They represent an ongoing effort by scientists and engineers to improve disaster resilience and demand focused Federal attention.

Disaster Profile: Earthquake

Following the 1994 Northridge Earthquake, the U.S. Geological Survey created a Working Group (WG99) to measure the likelihood of a large-scale earthquake affecting the San Francisco Bay area in the coming years. The WG99 determined that there is a 70% (+/- 10%) chance the region will experience a magnitude 6.7 or greater earthquake and an 80% chance of a magnitude 6.0 to 6.6 earthquake occurring before the year 2030.[11] The economic damage and potential deaths resulting from a large magnitude earthquake are considerable. Specifically, damages from a single large metropolitan earthquake could result in up to $100 billion dollars in direct losses.[12]

Reducing our risk of loss from earthquakes requires quantitative, predictive models of earthquake occurrence, processes, and effects. These models improve prediction capabilities and support early warning. At the same time, appropriate building codes and structural retrofitting are needed to protect against collapse during and after the quake and to prevent secondary or cascading hazards.

Grand Challenge 1

Provide Hazard and Disaster Information Where and When It Is Needed.

To identify and anticipate the hazards that threaten communities, a mechanism for real-time data collection and interpretation must be readily available to and usable by scientists, emergency managers, first responders, citizens, and policy makers. Developing and improving observation tools is essential to provide pertinent, comprehensive, and timely information for planning and response.

Challenges:

Improve data collection to increase understanding of the ways in which hazards evolve. Improve data collection through networks of sensors that enhance fundamental understanding of the nature and threats of hazard conditions. Sensors must become not only more accurate and reliable, but more specific. Improved Earth observations, remote sensing, and real-time containment detecting technologies are needed to provide comprehensive real-time data on hazardous conditions, aid hazard forecasting and allow researchers to recognize warning signs.

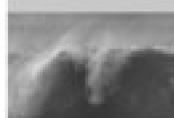
Create standards for sharing, storing and analyzing data. Standards for storing and sharing hazard-related data must be established so that information can be rapidly transferred and shared among agencies and made reliable for researchers and response managers. Universal tools should exist to facilitate the integrated analysis and distribution of hazard-related data across all Federal, state and local databases.

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed:

Key research requirements: Develop improved sensing capabilities and deploy expanded, modern, and integrated data collection systems that provide real-time data for use in modeling of hazardous conditions, consequence forecasting, and warnings. ■ Develop protocols for searchable, all-hazards Internet-accessible data systems. ■ Develop next generation network architectures for real-time data sharing from distributed sensors.

Major technology investments: Deploy an integrated, reliable information infrastructure that provides real-time access to data and models for hazard analysis, consequence forecasting, and rapid detection of negative outcomes. ■ Develop universally adopted standards for data sharing to speed transfer of information. ■ Incorporate geographical location data (using Geographic Information Systems (GIS) and Global Positioning Systems (GPS)) into systems that provide real-time, high quality, integrated social and environmental information for emergency response purposes.

Disaster Profile: Tsunami



Tsunamis are low probability disasters with very large impacts, as was demonstrated by the Indian Ocean tsunami. On December 26, 2004, a magnitude 9.0 earthquake occurred off the coast of Sumatra 18.6 miles (30 kilometers) below sea level. The earthquake and underwater landslides produced waves over 100 feet (30.48 meters) high along the Sumatra coastline which then traversed the Indian Ocean within 10 hours, reaching speeds of 500 miles (804.67 kilometers) per hour. Like the Indian Ocean tsunami, approximately 90% of tsunamis worldwide are caused by earthquakes, but volcanoes, landslides, and meteorites also can cause tsunamis. Tsunamis have occurred in the U.S. along the coasts of the Pacific Northwest, Hawaii, Alaska, and Caribbean and Pacific territories; volcano-induced local tsunamis are a particular risk for Hawaii and the Northern Mariana Islands.

Networks of sensors must be in place to detect tsunamis at sea, but it also is important to identify high-risk coastal communities and target those communities for hazard mitigation plans and projects. The technical systems for detecting and monitoring earthquakes and tsunamis must be complemented by national and local warning systems, trained local officials, and an educated and appropriate citizen response.

Grand Challenge 2

Understand the Natural Processes That Produce Hazards.

To improve forecasting and predictions, scientists and engineers must continue to pursue basic research on the natural processes that produce hazards and understand how and when natural processes become hazardous. New data must be collected and incorporated into advanced and validated models that support an improved understanding of underlying natural system processes and enhance assessment of the impacts.

Challenge:

Improve models and visualization techniques. Improved models and visualization techniques must exist to make data more usable for researchers and to aid forecasting. Modeling should be applied to all areas of study, including meteorological, geological, resource management, and social science applications. Advanced modeling techniques should be used to demonstrate the dynamic nature of evolving hazards, indicate potential adverse human and ecologic exposures, aid hazard prediction and assessment, and serve as roadmaps for dealing with future events.

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed:

Key research requirements: Continue and improve data collection and observations of hazard-related processes. ■ Develop and improve forecasting models and visualization techniques to provide timely and accurate information on the occurrence of hazardous events, consequences, and immediate steps that should be taken to reduce impacts. ■ Improve methods for validating these models. ■ Create and accelerate improvements in models of physical, chemical, and biological processes to enable a greater understanding of hazard interdependencies, predictive patterns, impacts, and cumulative effects on life, property, and the environment.

Major technology investments: Expand and improve the network that provides access to computational and simulation resources necessary for analysis and prediction.

Disaster Profile: Severe Ice Storm / Freezing

The property damage and loss of life due to ice storms and freezing can be catastrophic in terms of a disruption in services and damages caused to local business, crops and agriculture. The most severe impacts of such storms is loss of power, and extensive physical damages to structures. Additionally, states in which agriculture plays a large role in overall economic health suffer economic losses if freezing temperatures last more than a few weeks.

To reduce the impact of ice storms, continuous and useful information about the hazard must be made available to everyone affected. Geographic information systems can be used to provide integrated weather information and road conditions. Identifying the effects of wind on ice-laden structures and trees, of low visibilities in blowing snow, and the impact on just-in-time transportation systems can inform mitigation efforts and reduce disruption.

2004 Hurricane Season, The University of Wisconsin-Madison, Space Science and Engineering Center, November 30, 2004

Grand Challenge 3

Develop Hazard Mitigation Strategies and Technologies.

To prevent or reduce damage from natural hazards, scientists must invent—and communities must implement—affordable and effective hazard mitigation strategies, including land-use planning and zoning laws that recognize the risks of natural hazards. In addition, technologies such as disaster-resilient design and materials and smart structures that respond to changing conditions must be used for development in hazardous areas. By designing and building structures and infrastructure that are inherently hazard resilient, communities can greatly reduce their vulnerability.

Challenges:

Create resilient structures and infrastructure systems using advanced building technologies. Develop more advanced construction materials and technologies that create resourceful, intelligent, and self-healing structures. Structural systems must continue to be designed with disaster resilience in mind, and new materials and technologies must be available to create facilities that remain robust in the face of all potential hazards. "Smart" building technologies, which allow for self-diagnosis of damage and structural stability, should be employed.

Support structural advances with effective non-structural mitigation. All advances in building technology must be supported by appropriate nonstructural mitigation measures including land use and zoning regulations based on climatological and geological data. Community planning decisions should be designed to minimize damage and aid recovery.

Quantify the monetary benefits of disaster mitigation using economic modeling. Economic modeling is necessary to support investment decisions and demonstrate that substantial savings can be achieved by instituting disaster mitigation policies on a local and national level prior to investment in mitigation projects. Reliable data must be acquired to ground economic models empirically, and intangible and indirect impacts should be included in the model.

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed.

Key research requirements: Encourage investment in developing, modeling and monitoring impacts of cost-effective and beneficial mitigation technologies. ■ Continue development of smart structural systems that detect and respond to changes in structure and infrastructure condition, and that predict failure. ■ Continue development of new materials and cost-effective technologies to retrofit existing inventory of buildings, bridges, and other lifeline structures. ■ Create integrated all-hazard methodologies for engineered systems.

Disaster Profile: Severe Flooding

According to the NOAA National Weather Service, floods were the number-one natural disaster in the U.S. during the 20th century in terms of lives lost and property damage.[illegible] In 1993 alone, flooding in the Mississippi Basin resulted in an estimated $12 to $16 billion in damages.[illegible]

To prepare for floods, advanced modeling techniques must be employed to project real-time flood hazard impacts for large and small basins while integrated, area-targeted, multi-media systems issue warnings on flash floods and other rapid on-set disasters. The cumulative impacts on the hydrology and hydraulics of flooding and drought must be incorporated into land use measures. Finally, immediate analysis must be provided following the flood to facilitate recovery operations and restoration or removal of affected facilities.

Grand Challenge 4

Recognize and Reduce Vulnerability of Interdependent Critical Infrastructure.

Protecting critical infrastructure systems, or lifelines, is essential to developing disaster-resilient communities. To be successful, scientists and communities must identify and address the interdependencies of these lifelines at a systems level (e.g., communications, electricity, financial, gas, sewage, transportation, and water). Using integrated models of interdependent systems, additional vulnerabilities can be identified and then addressed. Protecting critical infrastructure provides a solid foundation from which the community can respond to hazards rapidly and effectively.

Challenges:

Develop science and technology to prevent cascading failures in public infrastructure systems. Develop tools and models to provide a more robust understanding of infrastructure interdependencies in order to protect the public infrastructure, to allow continuity of services, and to prevent cascading failures. Robust infrastructure systems should guard against damage from natural and technological hazards and feature redundant, rapidly resolving systems that allow any failures to be isolated and repaired with no disruption to other components. Additionally, infrastructures must be designed to protect people from secondary or cascading hazards. Risk assessment tools should be used to determine the impacts of planned development so appropriate measures can be taken to mitigate threats to infrastructure.

Enhance the ability to protect public health before and after a hazard event. Increased understanding of hazard events and their impact on public health can help protect the public before and after a hazard event. Communities should be designed to maintain sanitary conditions and prevent contamination to water supplies during and after hazard events. Scientific knowledge of potential threats to public health should be used in the creation of emergency response plans. Delivery of emergency services must be uninterrupted by the hazard. Public health conditions must be rapidly and effectively addressed to minimize the impact on people, animals, and the environment.

Disaster Profile: **Wildland Fire**

Wildland fires commonly occur naturally and may significantly contribute to forest health and wildlife habitat. However, a large buildup of underbrush and small trees coupled with the prolonged drought such as the one currently affecting the Western U.S. has increased the potential for large, catastrophic wildland fires in the Southwest and Western states. The 2003 California wildland fires caused more than 743,000 acres (3006.81 kilometers²) of brush and timber to be burned, 3,300 destroyed homes, 26 deaths.[17]

As with any threat, knowledge of the hazard is essential to reducing the danger. Enhanced knowledge of fuel sources and wildland fire behavior must continue to be incorporated into predictive models. Outreach programs must continue to be designed to more fully inform the public of the impacts of weather, insect and disease infestation, human actions, and other factors on wildland fires. Reducing unnaturally dense vegetation and the adoption of fire-safe practices such as safe fuel storage by all communities can mitigate against the spread of wildland fires, but additional steps also must be taken to reduce the spread of secondary hazards resulting from wildland fires (e.g., flooding and debris flows).

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed:

Key research requirement: Develop improved assessment methods for analyzing the vulnerability and interdependence of infrastructure systems. ■ Develop innovative assessment models for emergency response procedures including addressing all threats to public health rapidly and effectively.

Major technology investment: Develop information acquisition systems that can be used to validate evaluations of resilience and response. ■ Identify and deploy cost-effective technologies that ensure survivability of critical utilities and other infrastructures.

Grand Challenge 5

Assess Disaster Resilience Using Standard Methods.

Federal agencies must work with universities, local governments, and the private sector to identify effective standards and metrics for assessing disaster resilience. With consistent factors and regularly updated metrics, communities will be able to maintain report cards that accurately assess the community's level of disaster resilience. This, in turn, will support comparability among communities and provide a context for action to further reduce vulnerability. Validated models, standards, and metrics are needed for estimating cumulative losses, projecting the impact of changes in technology and policies, and monitoring the overall estimated economic loss avoidance of planned actions.

Challenges:

Support intelligent community planning and investment strategies and protect natural resources with comprehensive risk assessments. Risk assessments should be conducted to determine the likelihood and potential damages of hazard events and to identify at-risk communities or locations. Completed assessments can be used to guide investment and land-use decisions to protect the community and the natural environment. An integrated understanding of hazards requires understanding human behaviors that enhance or diminish the likelihood that potentially hazardous conditions will produce disastrous events.

Assess the resilience of the natural and human environment. Comprehensive assessments must include examination of the impact of natural and technological hazards on both the constructed and natural environment. Further, community planning must include steps based on scientific research to prevent loss of natural resources during a hazard event.

Learn from each hazard event. All hazard events should be analyzed and the results made public to support ongoing hazard research and future mitigation plans. Pre-disaster planning should be put into effect immediately following any hazard and should be the driving force behind all response and recovery actions for future events.

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed:

Key research requirements: Establish methods and standards for evaluation of resilience to hazards to include economic, ecological, and technological consequences of disasters. Base risk assessments on this data. ■ Use standard methods to gauge improvement in resilience following investments in planning and mitigation. This research must include contributions from all disciplines that play a role in understanding hazards and mitigation, including the social sciences.

Major technology investments: Complete risk assessments for Federal facilities, critical facilities, and at-risk communities. ■ Develop comprehensive pre-event recovery plans.

Grand Challenge 6

Promote Risk-Wise Behavior.

Develop and apply principles of economics and human behavior to enhance communications, trust, and understanding within the community to promote "risk-wise" behavior. To be effective, hazard information (e.g., forecasts and warnings) must be communicated to a population that understands and trusts the messages. The at-risk population must then respond appropriately to the information. Significant progress is being made, but this is an ongoing challenge that can only be met by effectively leveraging the findings from social science research.

Challenges:

Raise public awareness of local hazards. Reliable and integrated all-hazard data must be available to citizens and local decision makers to drive appropriate planning, mitigation, response, and recovery decisions.

Warn people with consistent, accessible, and actionable messages and a national all-hazards emergency communication system. Comprehensive emergency communication systems are needed to warn people and to specify actions to be taken in the event of a hazard. Emergency communications systems should utilize all available media outlets including mobile phones, cable television, and the Internet. Technology should be in place to deliver the messages in all locations no matter how remote, and to provide location-specific information. Messages should be crafted based on knowledge of likely human responses and should be provided by a recognizable authority in the given field (e.g., public health officials should provide public health messages). The seriousness of the threat must be conveyed and real-time information must be provided as hazard scenarios evolve.

Develop policies that promote risk-wise behavior and are based in social science research. Effective communications for eliciting appropriate public response to hazards must be developed from behavioral, population, and other social science studies. Research should lead to public awareness of the effectiveness of individual and institutional mitigation actions. Research is needed to better understand why people might expose themselves to hazards and what would motivate people to avoid hazards or take mitigating actions before and during a disaster.

To meet this Grand Challenge, the following key research requirements and major technology investments also must be addressed:

Key research requirements: Facilitate research in the social sciences to understand and promote individual and institutional mitigation actions in the face of hazards. ■ Develop an enhanced understanding of effective techniques for educating the public and gaining community support for preparedness and disaster prevention activities. ■ Research the effectiveness of, and human responses to, new communications technologies, including mobile phones, the Internet, and cable television on the delivery and successful use of public warnings.

Major technology investments: Design and implement a standardized messaging system for the general public and specific audiences. ■ Assemble and coordinate an integrated emergency communications system among response organizations at the Federal, state, and local levels.

The Way Forward

Sustained Federal investment in the Grand Challenges for Disaster Reduction will be facilitated in three stages: *Grand Challenges for Disaster Reduction (June 2005)*. This document provides an overview of the hazard vulnerabilities facing America and identifies the ten-year priorities for focused Federal investment in science and technology for disaster reduction.

The Five-Year Strategy (Spring 2006). This document will be implemented through the annual budgets of the science and technology agencies conducting appropriate research and development.

Annual Implementation Plans (2007 and beyond). The final stage in this process is the implementation of The Five-Year Strategy through the annual budgets of the science and technology agencies conducting the appropriate research and development. This implementation will entail a series of annual recommendations regarding Federal program planning and funding.

Together, the *Grand Challenges for Disaster Reduction* document, *The Five-Year Strategy*, and the annual implementation recommendations provide an evolving framework for Federal investments that enhance the Nation's disaster resilience.

Disaster Profile: **Drought**

Drought is a persistent and abnormal moisture deficiency, having adverse effects on vegetation, animals, or people. Slow-onset, non-structural impacts and lack of a uniform definition make drought a unique natural hazard. Compared to all natural hazards, droughts are, on average, the leading cause of economic losses. The estimated cost of the 1988–1989 drought was $39 billion nationwide and was, at the time, the greatest single year hazard-related loss ever recorded. In 2004, many Western states experienced their fifth consecutive year of drought and one of the worst droughts of the past century.

The slow onset of drought over space and time can only be identified through the continuous collection of climate and hydrologic data. To enhance decisions and minimize costs, drought warning systems must provide credible and timely drought risk information including drought monitoring and prediction products.

Conclusion

We cannot avoid hazards, but we can act to minimize and reduce their impacts. After all, hazards do not become disasters unless the communities they touch are unprepared to deal with them. In short, disaster resilience must become inherent to our national culture and a natural right of all people. This report establishes a framework for Federal investment in science, engineering, and technology to reduce America's disaster vulnerability. Successfully reducing disasters depends upon sustained investment in these Grand Challenges and in recognizing that hazards are inherent on our complex environmental, constructed, agricultural, political, and social systems.

Aftermath of Hurricane Fran, September 1996, Photograph by Dave Gatley, from FEMA Photo Library

Appendix A: Research Requirements and Technology Investments by Hazard

Grand Challenge 1: **Provide Hazard and Disaster Information Where and When It Is Needed.**

Drought. Improve the information infrastructure to reach and educate those affected by drought and those providing drought information.

Earthquake. Continue to deploy and maintain modernized and expanded systems to collect data for use in the prediction of earthquake occurrences and their effects.

Flood. Develop improved hundred-year flood plain maps. ■ Develop flood risk maps based on future development of watersheds so that maps stay current and property owners understand how development impacts their vulnerability and risk.

Public Health/Environmental. Identify mechanisms and processes and corresponding prevention or reduction strategies for health and ecological impacts.

Severe Weather. Accelerate development of integrated data observation systems, models, and forecast platforms to reduce the area placed under warnings and to reduce costly and unnecessary evacuations. ■ Capture and use improved remotely sensed observations in high space and time resolution of atmospheric and land surface data over the entire globe. ■ Use improved observational, assimilation, and modeling techniques, such as four-dimensional, high-time, and space resolution observations of atmospheric moisture.

Technological. Develop GIS databases at local, state, and national levels to map critical infrastructure, industry, public health services, and other facilities in order to identify locations of technological disasters, and predict the direction and extent of damage.

Volcano. Build a database of hazard/volcanic history information, as well as information on population placement and local facilities (highways, dams, airports, etc.) that could be impacted by different types of eruptions.

Wildland Fire. Increase the emphasis on space-based thermal fire detection, monitoring, and mapping capabilities. More fully integrate information across hazards to identify and illustrate interactions, including environmental benefits of natural wildland fires (e.g., relationships of drought to potential fire severity, and then to the extended risk of flooding after a catastrophic wildland fire).

Grand Challenge 2: **Understand the Natural Processes That Produce Hazards.**

Drought. Build and deploy a national instrument system capable of collecting climate and hydrologic data to ensure drought can be identified spatially and temporally. ■ Develop an integrated modeling framework to quantify predictions of drought and drought impacts useful in decision making.

Earthquake. Improve earthquake hazard assessments to include the effects of local soil conditions, local geologic structures, earthquake mechanics (e.g., directivity and stress drop) and recent seismic activity, and to provide estimates of the uncertainty. ■ Develop improved realistic and reliable models of fault and earthquake processes including strain accumulation and earthquake nucleation, fault rupture and arrest, and seismic wave generation and propagation.

Flood. Project real-time flood hazard impacts for large and small basins. ■ Develop improved real-time models that capture the interdependencies of floods. ■ Develop enhanced models for rapid assessment of stream stability. ■ Improve sensor network design and operational capabilities to provide early data needed for predicting and sensing hazards using physical process models.

Public Health/Environmental. Improve disease and environmental monitoring to identify, describe, collect, analyze, and interpret emerging infections and environmental agents (e.g., organisms, toxic substances, etc.). These monitoring systems must be accurate and specific, particularly for threat agents. ■ Integrate biological, physical, and chemical models to provide accurate and timely forecasts.

Severe Weather. Develop models to better forecast and track intensity changes of tropical storms and associated impacts (e.g., storm surge, inland flooding and tornado outbreaks).

Technological. Develop real-time contaminant-specific detectors, alarm systems, and data analysis tools. ■ Study the basic mechanisms behind contaminant fate and transport in air, water, and through the earth.

Volcano. Incorporate real-time monitoring of all active volcanoes at a level appropriate to the risk they pose. ■ Build models for distribution of erupted products. ■ Develop models that incorporate data on seismicity, deformation, gravity changes, gas emissions, magma movement, and other parameters to distinguish between magmatic and geothermal unrest—seismic tomography evaluation of magma reservoirs.

Wildland Fire. Improve understanding of the processes of wildland fire behavior, fuel development, and condition at a landscape scale—and interactions between these factors and weather and climate at regional to global levels—to accurately model and predict the potential occurrence, behavior, and impacts of wildland fire on resources, on the environment, and on physical infrastructure.

Grand Challenge 3: **Develop Hazard Mitigation Strategies and Technologies.**

Drought. Develop decision support tools that proactively reduce the potential severity of drought impacts. ■ Incorporate drought monitoring and prediction products into mitigation plans in time to make changes to natural resources planning.

Earthquake. Use scientific research to develop appropriate building/design code provisions to mitigate progressive collapse vulnerability following earthquake, wildland fire, or other events, including earthquake-triggered landslides. ■ Improve understanding of building response to strong shaking through large-scale laboratory testing and instrumentation of buildings for real-time monitoring.

Flood. Identify and mitigate impacts of development in community plans before development occurs. ■ Provide transportable and easily installed flood mitigation systems to support flood fights.

Public Health/Environmental. Model outcomes of known and predictable natural and technological hazards on at-risk populations and ecosystems in specific geographic areas. ■ Develop environmental decontamination capabilities for chemical, biological, radiological, and hazardous substances.

Severe Weather. Integrate knowledge of the climatology of local meteorology into building codes, the location of new development, populations, and materials.

Technological. Improve response and planning capabilities, to include the use of contingency plans. ■ Develop improved, security based design standards for new facilities, transportation containers, and storage devices.

Volcano. Institute a practice in which land use planners incorporate information from volcano hazard maps in their projects as appropriate.

Wildland Fire. Implement integrated landscape level wildland fire management plans for all Federal and state agencies and for all lands based on detailed risk analysis. ■ Design and evaluate building material with improved wildland fire safety characteristics.

Grand Challenge 4: **Recognize and Reduce Vulnerability of Interdependent Critical Infrastructure.**

Drought. Collect information to support policies that restore urban and rural communities in a manner that reduces long-term vulnerability to critical infrastructures while enhancing resilience.

Earthquake. Develop performance criteria based on actual infrastructures, research, and other work for design and retrofit methods.

Flood. Understand land-use measures and the cumulative impacts on the hydrology and hydraulics of flooding and drought. ■ Thoroughly develop evacuation plans for flood plains. ■ Identify the potential impact of flooding on water, waste-water, and sewer systems, and make them more resistant.

Public Health/Environmental. Assure that access to hospitals and emergency medical services is maintained following hazard events.

Severe Weather. Improve development of appropriate response, contingency, and evacuation community plans based on knowledge of extreme weather events derived from long-term data collection and analysis. ■ Develop or identify cost-effective technologies that ensure that critical utilities and other infrastructure survive severe weather events.

Technological. Develop more advanced computational models for the design and evaluation of mitigation methods and strategies for all types of infrastructures and industries. ■ Automate regional GIS-based emergency response plans and integrate plans from industry, critical infrastructure and resources, and local communities.

Volcano. Develop evacuation plans and incorporate in all community response plans.

Wildland Fire. Research wildland fire safe practices (e.g., fuel management in interface zones) in all communities either voluntarily or in response to regulatory action. ■ Improve wildland fire hazard assessment methods for communities in the wildland-urban interface to include community and building design and the logistics of access and egress for disaster responders.

Grand Challenge 5: **Assess Disaster Resilience Using Standard Methods.**

Drought. Provide drought relief based on real-time information on the extent and intensity of drought events around the globe. ■ Develop standards for assessment of social and economic costs of direct and indirect drought impacts.

Earthquake. Extend the computational models to serve as a tool for recovery planning and incorporate them into mitigation strategies. ■ Collect cost-benefit information on the value of monitoring and notification capabilities.

Flood. Facilitate immediate analysis of flood parameters following disaster so as to assist recovery operations and restoration or removal of impacted facilities.

Public Health/Environmental. Develop and institute recovery programs for human and animal health (e.g., injury rehabilitation, mental recovery, suicide prevention, domestic violence, water system evaluation, safety of food, vector control, epidemiological monitoring, etc.). ■ Develop pilot projects for recovery and restoration techniques (e.g., replanting of multiple species in areas decimated by diseases or parasitic invasion, diagnostic tools for mental health).

Severe Weather. Coordinate inter-agency, detailed post-storm assessment of damage, injuries, and deaths.

Technological. Design a suite of new non-intrusive, environmentally sound, and rapidly deployable clean-up technologies for contaminated soil, water, and built surfaces. ■ Identify and implement new disposal and waste reduction techniques.

Volcano. Disseminate information to communities surrounding volcanoes regarding the removal of volcanic ash, timeline for return to evacuated areas after an eruption, and potential hazards that exist after an eruption. ■ Make information available to the public and to emergency responders regarding post event recovery operations, decontamination efforts, and the post-hazard environment.

Wildland Fire. Extend awareness and response and warning systems that address possible post-catastrophic fire events such as debris flows. ■ Anticipate recovery in advance based on model predictions of wildland fire effects and an understanding of effectiveness of both natural regeneration and post-fire emergency rehabilitation treatments and restoration treatments at reducing damage to ecosystems and water resources from wildland fires.

Grand Challenge 6: **Promote Risk-Wise Behavior.**

Drought. Implement a drought warning system capable of providing credible and timely drought risk information to enhance decisions and minimize costs associated with drought.

Earthquake. Create a uniform and reliable alert system, including consistent classification schemes for disaster severity. ■ Predict effects, impacts, and cascading failures of an earthquake as the event is occurring and deliver the information in the first five to ten minutes after the event. ■ Develop automated early-warning systems capable of reducing impact to critical infrastructure in urban centers at a distance from the earthquake epicenter. ■ Improve real-time communication between the weather-forecasting community and earth science community responsible for landslide warnings.

Flood. Develop integrated, area-targeted, multi-media systems for issuing warnings on flash floods and other rapid on-set disasters. ■ Use social science research to coordinate public education to help people understand and respond to warnings. ■ Institute a practice in which land use planners incorporate information from flood and landslide hazard maps in their projects, as appropriate.

Public Health/Environmental. Develop and improve communication of warnings for health and environmental hazards. ■ Evaluate the scientific basis for individual actions before, during, and after an event to reach interagency agreement on best practices.

Severe Weather. Direct automated calls (e.g., reverse 911) to those at risk. ■ Accelerate improvements in predictive models through enhanced physical understanding, data assimilation, and spatial resolution.

Technological. Facilitate a scientifically literate national and local media to report on the facts behind technological disasters, including their impacts and ways by which the public can mitigate effects. ■ Improve rapid risk assessment methods for providing immediate public health information during a disaster.

Volcano. Develop a standardized messaging system for use by the general public and specific audiences (e.g., the FAA).

Wildland Fire. Improve development and implementation of effective and accessible communication systems to inform the public of the impacts of policy alternatives, weather, insect and disease infestation, human actions and other factors on risks to communities, ecosystems, and environment from wildland fire. Also, implement communication systems for effective, proactive community involvement in risk analysis and decision making. ■ Develop communication capabilities that enable complete and timely use of tools for assessment and planning. ■ Integrate real-time weather information with hazard warning systems, (e.g., linking precipitation forecasts with post-fire debris flow warnings.)

Appendix B: Key Terms

All-hazards approach—an integrated hazard management strategy that incorporates planning for and consideration of all potential natural and technological hazards, including terrorism.

Built environment—the Nation's constructed facilities, buildings, transportation, and industrial infrastructure systems.

Critical infrastructure—the physical and cyber-based systems that are essential to the minimum operations of the economy and government.

Disaster—a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Disaster risk—the chance of a hazard event occurring and resulting in disaster.

Hazard—a natural or human-caused threat that may result in disaster when occurring in a populated, commercial, or industrial area.

Hazard event—a specific occurrence of a hazard.

Hazard mitigation—any action taken to reduce or eliminate the long-term risk to human life and property from natural hazards.

Hazard risk—the chance of a hazard event occurring.

Natural disaster—a disaster that results from a natural hazard event.

Natural hazard—a hazard that originates in natural phenomena (e.g., hurricane, earthquake, tornado).

Resilience/resilient—the capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Risk—the probability of harmful consequences or expected losses (death and injury, losses of property and livelihood, economic disruption, or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Technological disaster—a disaster that results from a technological hazard event.

Technological hazard—a hazard that originates in accidental or intentional human activity (e.g., oil spill, chemical spill, building fires, terrorism).

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Appendix D: About the National Science and Technology Council

About the National Science and Technology Council

The National Science and Technology Council (NSTC), a cabinet-level council, is the principal means for the President to coordinate science and technology policies across the Federal Government. NSTC acts as a virtual agency for science and technology to coordinate the diverse parts of the Federal research and development enterprise.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research to improving transportation systems and strengthening fundamental research. This council prepares research and development strategies that are coordinated across Federal agencies to form an investment package aimed at accomplishing multiple national goals.

To obtain additional information regarding the NSTC, contact the NSTC Executive Secretariat at (202) 456-6101.

About the Committee on Environment and Natural Resources (CENR)

The purpose of the Committee on Environment and Natural Resources (CENR) is to advise and assist the NSTC to increase the overall effectiveness and productivity of Federal research and development efforts in the area of the environment and natural resources. This includes maintaining and improving the science and technology base for environmental and natural resource issues, developing a balanced and comprehensive research and development program, establishing a structure to improve the way the Federal Government plans and coordinates environmental and natural resource research and development in both a national and international context, and developing environment and natural resources research and development budget crosscuts and priorities.

Committee on Environment and Natural Resources Membership

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- Michael O'Connor (USACE)
- Ken Olden (HHS)
- Marcus Peacock (OMB)
- Vahid Majidi (DOJ)
- Jacqueline Schafer (USAID)
- Veronica Stidvent (Labor)
- John Turner (State)
- Samuel Williamson (NOAA)

About the Subcommittee on Disaster Reduction

Mitigating natural and technological disasters requires a solid understanding of science and technology, rapid implementation of research information into disaster reduction programs and applications, and efficient access to diverse information available from both public and private entities. The Subcommittee on Disaster Reduction provides a unique Federal forum for information sharing, development of collaborative opportunities, formulation of science- and technology-based guidance for policy makers, and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks.

Chartered in 1988, the Subcommittee on Disaster Reduction is a subcommittee of the Committee on Environment and Natural Resources, an element of the President's National Science and Technology Council. The Chair, the Vice Chair for Policy, and the Vice Chair for Science and Technology are each selected by the White House Office of Science and Technology Policy and serve a three-year term. The heads of relevant agencies and departments annually designate lead representatives to the SDR.

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Dr. Phil Pasteris

United States Department of Agriculture / Forest Service

Dr. Susan Conard (Member)

Grand Challenges Summary

Provide Hazard and Disaster Information Where and When It Is Needed.

- Improve data collection to increase understanding of the ways in which hazards evolve.
- Create standards for sharing, storing, and analyzing data.

Understand the Natural Processes That Produce Hazards.

- Improve models and visualization techniques.

Develop Hazard Mitigation Strategies and Technologies.

- Create resilient structures and infrastructure systems using advanced building technologies.
- Support structural advances with effective nonstructural mitigation.
- Quantify the monetary benefits of disaster mitigation using economic modeling.

Recognize and Reduce Vulnerability of Interdependent Critical Infrastructure.

- Develop science and technology to prevent cascading failures in public infrastructure systems.
- Enhance the ability to protect public health before and after a hazard event.

Assess Disaster Resilience Using Standard Methods.

- Support intelligent community planning and investment strategies and protect natural resources with comprehensive risk assessments.
- Assess the resilience of the natural and human environment.
- Learn from each hazard event.

Promote Risk-Wise Behavior.

- Raise public awareness of local hazards.
- Warn people with consistent, accessible, and actionable messages and a national all-hazards emergency communication system.
- Develop policies that promote risk-wise behavior and are based in social science research.

Attachment 5

The *Grand Challenges for Disaster Reduction* outlines a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the tornado-specific implementation plan. See also sdr.gov for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. A tornado is a violently rotating column of air extending from a thunderstorm to the ground. Tornadoes may appear nearly transparent until dust and debris are picked up or a cloud forms within the funnel. The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. The most violent tornadoes are capable of tremendous destruction with wind speeds of 112 m/s (250 mph) or more. The swath of damage can be in excess of 1.6 km (one mile) wide and 80.5 km (50 miles) long.

Tornadoes come in all shapes and sizes and can occur anywhere in the United States at any time of the year. Tornadoes have occurred in every state, but they are most frequent east of the Rocky Mountains during the spring and summer months. In the southern states, peak tornado season is March through May, while peak months in the northern states are during the summer. Tornadoes are most likely to occur between 3 and 9 p.m. but can happen at any time.

In 2004, Congress recognized the unique role of wind hazards and created an Interagency Working Group consisting of NIST, NSF, NOAA, and FEMA to plan, manage, and coordinate windstorm impact reduction for the Nation.

IMPACTS. Although tornadoes occur in many parts of the world, they are found most frequently in the United States. In an average year, 1,200 tornadoes cause 70 fatalities and 1,500 injuries nationwide.[1] The most expensive tornado outbreak in United States history and the deadliest of the year occurred May 3 and 4, 1999 in Oklahoma and Kansas. In less than 21 hours, a total of 74 tornadoes touched down across the two states, with as many as four tornadoes from different storms on the ground at once.

One of those storms, an F-5 tornado, the strongest on the Fujita Tornado Scale, moved along a 61-kilometer (38-mile) path, from Chickasha through south Oklahoma City and the suburbs of Bridge Creek, Newcastle, Moore, Midwest City, and Del City. With 8,000 buildings[2] damaged, the Oklahoma City tornado is the most expensive single tornado in history, causing about a billion dollars in damage. In all, the tornadoes killed 46 people, injured 800, and caused $1.5 billion in damage.[3]

TORNADO

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An element of the National Science and Technology Council

The event proved the effectiveness of the watch and warning program in the modernized National Weather Service, showing improvement with an average warning lead time of 18 minutes for the event (up from a national 11-minute average), with some areas receiving more than 30 minutes notice before being hit. NOAA storm researchers estimate that more than 600 people would have died in the absence of watches and warnings.[1]

Grand Challenges for Disaster Reduction: Priority Interagency Tornado Implementation Actions

GRAND CHALLENGE #1: **Provide hazard and disaster information where and when it is needed.**

- ■ Assess and fill gaps in observations, training, technology, capacity, and organization that may prohibit efficient exchange of information;
- ■ Promote collaborations and partnerships between Federal agencies through existing facilities (e.g., Hazardous Weather Test Bed, the Short Term Prediction Research and Transition Center, the Joint Center for Satellite Data Assimilation, and the Hydrometeorology Test Bed) to transition from research to operations;
- ■ Provide data compatible with the operational communications and dissemination systems (e.g., the National Weather Service) to inform forecasts;
- ➢ Improve resolution (space and time) of real time in situ and remotely sensed measurements of the near-storm environment;
- ✣ Create stable, efficient, fast data assimilation models with appropriate atmospheric characterization to produce tornado warnings up to 45 minutes in advance, severe thunderstorm warnings up to 60 minutes in advance, and watches up to 8 hours in advance;
- ✣ Speed delivery of remote-sensing satellite products.

GRAND CHALLENGE #2: **Understand the natural processes that produce hazards.**

- ■ Improve predictive models through enhanced physical understanding, data assimilation, and spatial resolution;
- ■ Deploy new sensors, such as dual polarized radars, to better understand cloud microphysics;
- ➢ Develop integrated data observation systems, models, and forecast platforms to reduce costly and unnecessary evacuations;
- ➢ Verify tornado initiation and dissipation by conducting field experiments and gathering new data;
- ➢ Improve data assimilation techniques for high-resolution models;
- ✣ Deploy new sensors, such as phased array radar, to increase spatial and temporal input needed for high-resolution, small-scale numerical models;
- ✣ Develop operational forecast models to track tornado intensity changes and provide a better understanding of the expected frequency and magnitude of these events.

GRAND CHALLENGE #3: **Develop hazard mitigation strategies and technologies.**

- ■ Evaluate the response of the built environment to tornadoes by investigating load path, ultimate capability conditions, and the building envelope;
- ■ Assess the impact of wind and windborne debris;
- ■ Explore the near-ground and channeling/shielding effects of winds on buildings through testing and instrumentation;
- ➢ Provide a technical basis for revised standards and codes that integrate local climatological and meteorological knowledge to improve standards for the built environment, improve safety, and reduce structural loss during tornadoes.

Key: ■ Short Term Action (1-2 years) ➢ Medium Term Action (2-5 years) ✣ Long Term Effort (5+ years)

GRAND CHALLENGE #4: **Reduce the vulnerability of infrastructure.**

- ▹ Develop and deploy new technologies that aid in better design, rapid repair, and restoration of critical infrastructure and other essential facilities;
- ▹ Measure the response of bridges and other highway structures to tornadoes, including stability, serviceability, and functionality leading up to and through the tornado event;
- ▹ Develop mitigation strategies with local authorities, such as burying power and communication cables.

GRAND CHALLENGE #5: **Assess disaster resilience.**

- ■ Coordinate inter-agency, detailed post-storm assessment of damage, injuries, and deaths;
- ■ Assess local preparedness and enhance local resilience through the National Weather Service Storm Ready Program.

GRAND CHALLENGE #6: **Promote risk-wise behavior.**

- ■ Educate individuals, communities, states, and the Federal agencies about the risks associated with tornadoes and appropriate actions to take;
- ■ Distribute seasonal outlooks, explain longer lead time warnings, and emphasize preparedness and the importance of taking appropriate action during a watch or warning;
- ■ Employ communication and dissemination strategies for extended warnings and probabilistic forecasts based on improved social science research into individual response;
- ■ Informed community planning and annual drills will lead to more effective warnings and evacuations;
- ■ Direct automated calls to those at risk (e.g., severe-911);
- ✧ Create interactive, portable, and adaptable forecast, warning, and decision support systems based on high-resolution numerical models, high-resolution observations, and improved algorithms to alert emergency managers, emergency personnel, and individuals in real time about locally occurring severe storms.

Key: ■ Short Term Action (1-2 years) ▹ Medium Term Action (2-5 years) ✧ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this tornado-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Risk assessments based on regional tornado climatology and seasonal outlooks provide local information to those at risk.

Communities at risk know when a hazard event is imminent. Predicting tornadoes by community, neighborhood, and specific street address will yield better, more actionable warnings and fewer lives lost. Real-time information dissemination and decision-support tools will be used by emergency personnel and local, state, and Federal emergency management officials.

Individuals at risk are safe from hazards. Tornado impact reduction practices at all levels of government will be aided by training and outreach programs to build a ready-public. Informed planning and annual drills will lead to more effective warnings and evacuations.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Public-private partnerships fostering technology transfer programs will enhance response and recovery capabilities using improved tornado damage and loss estimation tools. Standards and technologies will enable cost-effective, state-of-the-art tornado-resistant provisions to be adopted as part of state and local building codes.

Acronyms

FEMA Federal Emergency Management Agency
NIST National Institute of Standards and Technology
NOAA National Oceanic and Atmospheric Administration
NSF National Science Foundation

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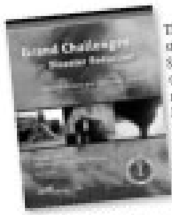
Attachment 6



The *Grand Challenges for Disaster Reduction* outlines a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the hurricane-specific implementation plan. See also sdr.gov for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. A hurricane develops when a tropical storm intensifies and winds reach 74 miles per hour. On average, there are six hurricanes in the Atlantic Ocean each year during hurricane season (June–November). Over a three-year period, approximately five hurricanes strike the United States coastline between Texas and Maine.[1] When hurricanes move onto land, the heavy rain, strong winds, and waves can damage communication, transportation, and utility infrastructures.

IMPACTS. According to FEMA, hurricanes account for seven of the top ten most costly disasters in United States history. The state of Florida was struck by four major hurricanes in 2004 with losses totaling $42 billion.[2] This was considerably more than the losses resulting from Hurricane Andrew in 1992, which had set the standard for single hurricane losses in the United States. The 2005 hurricane season included 27 named storms and 15 hurricanes, 6 of which struck the United States.[3]

The losses due to Hurricanes Katrina, Rita, and Wilma in 2005 are still being determined, but early estimates place damages from Hurricanes Katrina and Rita upwards of $150 billion.[4]

This dwarfs the losses due to any disaster in the United States and approaches a significant percentage of the United States Gross Domestic Product.

Recent storms demonstrated how hurricanes can affect the entire United States and its economy, from energy to raw materials to food supplies. Minimizing the impacts of hurricanes depends upon constant, sound land-use planning and development decisions as well as effective response immediately prior to storm landfall. The multi-agency U.S. Weather Research Program, authorized by Congress in 1994, placed the improvement of hurricane forecasts as its highest priority in 1997. Since then, the program has significantly improved hurricane track forecasts and how those forecasts and warnings are communicated to individuals. In 2004, Congress recognized the unique role of wind hazards and created an Interagency Working Group consisting of NIST, NSF, NOAA, and FEMA to plan, manage, and coordinate windstorm impact reduction for the Nation.

HURRICANE

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Grand Challenges for Disaster Reduction: Priority Interagency Hurricane Implementation Actions

GRAND CHALLENGE #1: **Provide hazard and disaster information where and when it is needed.**

- ■ Improve mechanisms for information exchange between Federal agencies involved in wind hazard reduction, state and local decision makers, and non-Federal stakeholders;
- ▹ Assess and fill gaps in observations, training, technology, capacity, information, and organization on the Federal, state, and local level;
- ▹ Accelerate development and deployment of integrated Earth observing systems, models, and forecast platforms to warn those who are directly at risk.

GRAND CHALLENGE #2: **Understand the natural processes that produce hazards.**

- ■ Build on accomplishments of the U.S. Weather Research Program to accelerate improvements in hurricane forecasts;
- ▹ Improve global coverage of scatterometer and radiometer space-based remote sensing systems;
- ▹ Develop high-resolution global and regional cloud-resolving forecast models to simulate and forecast hurricane structure, track, and intensity;
- ▹ Improve understanding and modeling of atmosphere-ocean interactions; understand the physics of hurricane genesis;
- ▹ Improve airborne observing capabilities, including the use of remotely piloted vehicles;
- ▹ Increase density of and strengthen in situ and surface-based remote sensing platforms over land and ocean and develop mobile platforms and networks to opportunistically gather data needed for post-storm assessment and model enhancements;
- ✦ Develop sophisticated decision support systems (e.g., HAZUS) for risk assessment and impact prediction.

GRAND CHALLENGE #3: **Develop hazard mitigation strategies and technologies.**

- ■ Exchange information between all levels of government about interpreting hurricane risk assessments, forecasts, building codes and best building practices, protection of critical infrastructure, and public education on risk, response, and mitigation. Pay particular attention to individuals who are often at greatest risk, such as the economically, socially, and medically disadvantaged;
- ▹ Develop a comprehensive wind storm climatology to provide the technical basis for improved building codes and predictive numerical engineering models of wind effects on structures;
- ▹ Identify expected inter-annual, decadal, and multi-decadal changes in hurricane activity and intensity;
- ▹ Develop improved methods for assessing risk, social vulnerability, and ecosystem impacts to inform mitigation choices in coastal areas.

GRAND CHALLENGE #4: **Reduce the vulnerability of infrastructure.**

- ▹ Examine the interaction between wind, storm surge, and shallow water waves to determine the impact on building foundations, critical infrastructure, and vegetation;
- ▹ Assess the vulnerability of critical communication, transportation infrastructure, and essential facilities to hurricanes.

Key: ■ Short Term Action (1-2 years) ▹ Medium Term Action (2-5 years) ✦ Long Term Effort (5+ years)

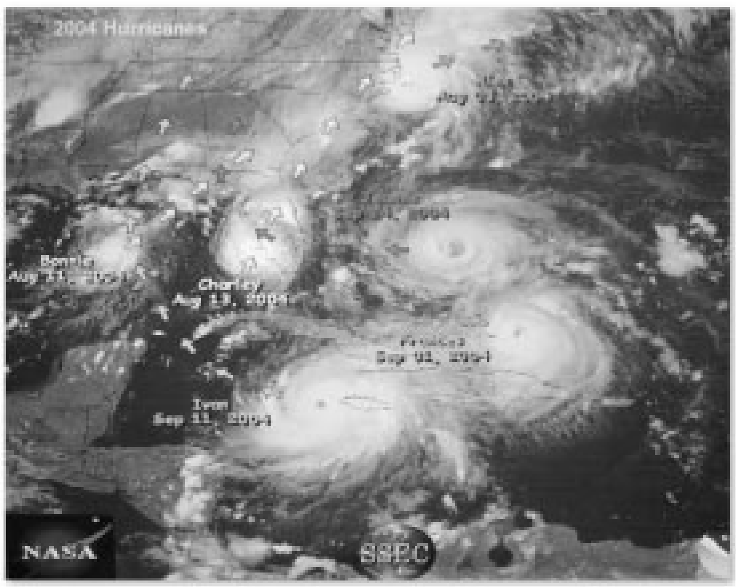
- Develop an improved loss estimation modeling tool (e.g., HAZUS);
- Create robust and storm-ready communication systems, essential facilities, and transportation infrastructure.

GRAND CHALLENGE #5: **Assess disaster resilience.**

- Assess structural and non-structural hurricane protection, including natural barriers, levees, and land use;
- Support intelligent community planning and investment strategies and protect natural resources with comprehensive risk assessments;
- Develop comprehensive pre-event recovery plans;
- Assess response and recovery of terrestrial and coastal ecosystems to hurricane damage.

GRAND CHALLENGE #6: **Promote risk-wise behavior.**

- Support social science research on individual, organizational, and community responses to disaster warnings;
- Identify common characteristics of risk-wise behavior and factors facilitating effective warning compliance;
- Identify obstructions to the most effective communication of risk from time scales of hours before landfall to decades in the future;
- Promote individual understanding of forecast and warning statements—in particular, an understanding of the uncertainty in this information—and encourage appropriate actions;
- Facilitate more effective communication and use of communication systems (i.e., direct automated calls to those at risk) to improve public understanding of hurricane risks, mitigation procedures, and evacuation procedures;
- Improve development of appropriate response, contingency, and evacuation community plans based on knowledge of extreme weather events derived from long-term data collection and analysis.



Key: ■ Short Term Action (1-2 years) ▹ Medium Term Action (2-5 years) ✧ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this hurricane-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Combined assessment methods will allow better understanding of structural, social, and economic impacts of hurricanes.

Communities at risk know when a hazard event is imminent. Through improved observation technologies and improved modeling capabilities, forecasters will have the necessary information to provide accurate and understandable forecasts of hurricane track, intensity/structure, sea state/waves, storm surge, winds, precipitation, flooding, and inundation up to 5 days prior to landfall. This improved capability will lead to improved warning accuracy and lead time and more efficient and effective preparedness, including evacuation.

Individuals at risk are safe from hazards. The coordinated distribution of information about risk and preparedness combined with effective decision-making tools will lead to more timely and accurate warnings as well as appropriate and efficient evacuation.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. New, more accurate methods for understanding and assessing risk perception and risk communication including the utilization and effectiveness of non-structural mitigation measures and improved structural design will make communities more disaster resilient.

Acronyms

FEMA	Federal Emergency Management Agency
HAZUS	Hazards United States Loss Estimation
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation

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Attachment 7

WINTER STORM

The *Grand Challenges for Disaster Reduction* is a ten-year strategy crafted by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR). It sets forth six Grand Challenges that, when addressed, will enhance community resilience to disasters and thus create a more disaster-resilient Nation. These Grand Challenges require sustained Federal investment as well as collaborations with state and local governments, professional societies and trade associations, the private sector, academia, and the international community to successfully transfer disaster reduction science and technology into common use.

To meet these Challenges, the SDR has identified priority science and technology interagency implementation actions by hazard that build upon ongoing efforts. Addressing these implementation actions will improve America's capacity to prevent and recover from disasters, thus fulfilling our Nation's commitment to reducing the impacts of all hazards and enhancing the safety and economic well-being of every individual and community. This is the winter storm-specific implementation plan. See also sdr.gov for other hazard-specific implementation plans.

What is at Stake?

DEFINITION AND BACKGROUND. Each year, nearly every state in the United States faces the hazards of winter weather, heavy snow and rain, freezing rain, strong winds, and cold temperatures. Despite the societal and economic impacts, the natural processes that produce severe winter weather and its effects are not well understood. Real-time measurements of the structure and composition of clouds, which are important for understanding the processes producing precipitation, do not exist. Techniques for measuring snow and snowfall depend solely on manual observations, and the resulting datasets are often incomplete and inaccurate. In fact, two different datasets of weather-related mortality report opposite findings. One dataset (the National Climatic Data Center's Storm Data) records more heat-related deaths per year than cold-related deaths, whereas another dataset (the National Center for Health Statistics Compressed Mortality Database) records the opposite, with nearly four times the number of cold-related deaths than heat-related deaths.[1]

IMPACTS. Currently, forecasting winter weather is difficult and high-risk because the same weather event occurring at different times of the day can produce drastically different societal results. For example, an inch of wet snow during rush hour on a weeknight will produce a dramatically different impact than an inch of wet snow on Saturday night. Also, imprecise winter weather

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predictions lead to expensive, reactive economic accommodation of winter weather rather than a more proactive economic stance that could minimize costs.

Weather information providers and consumers have not embraced a probabilistic approach to these forecasting challenges that would help significantly decrease the nearly 7,000 deaths, 600,000 injuries, and 1.4 million accidents a year that occur due to adverse winter driving conditions, by extending winter weather watch and warning lead times.[1]

Grand Challenges for Disaster Reduction: Priority Interagency Winter Storm Implementation Actions

GRAND CHALLENGE #1: **Provide hazard and disaster information where and when it is needed.**

- ■ Assess and fill gaps in observations, training, technology, capacity, and organization that may prohibit efficient exchange of information;

- ■ Establish a depository for winter weather data in a common data format;
- > Provide accurate identification of precipitation type and area of occurrence to within 10 km (6 miles) resolution to emergency managers and response personnel;
- > Develop GIS-data-based, integrated weather information, road availability information, satellite tracking, satellite delivery, and interaction to support an integrated winter weather decision support system.

GRAND CHALLENGE #2: **Understand the natural processes that produce hazards.**

- ■ Understand the transition region between rain and snow by researching the thermodynamic, dynamic, and microphysical environment;
- > Measure precipitation at the surface and aloft, from multi-wavelength polarization radar, from moisture information in the transition zone, and vertical air motion;
- > Develop 36-hour geo-reference forecast for counties that describes the probability of severe winter weather;
- > Deploy networks of automatic snow sensors to measure liquid equivalent in real time;
- > Develop new remote-sensing and *in situ* techniques for measuring the constituent particles inside clouds, and lower-atmospheric temperature and moisture fields;
- > Develop flexible and adaptable decision support tools based on radar/satellite/*in situ* observations that, through joint data assimilation, provide critical information on cloud microphysics,

Key: ■ Short Term Action (1–2 years) > Medium Term Action (2–5 years) + Long Term Effort (5+ years) rain/freezing/frozen precipitation, banded structures, orographic influences, and spatial patterns and their evolution;

- ➤ Develop accurate quantitative precipitation forecasts, especially for freezing rain and snow accumulations, which use improved observational, assimilation, and modeling techniques (e.g., space resolution observations of atmospheric pressure).

GRAND CHALLENGE #3: **Develop hazard mitigation strategies and technologies.**

- ■ Understand social and economic barriers to and incentives for adoption of mitigation strategies and winter storm preparations;
- ✱ Expand winter storm climatologies to provide improved engineering standards for ice, wind, and snow on structures (e.g., buildings and communications, electricity, gas, sewage, transportation and water infrastructure).

GRAND CHALLENGE #4: **Reduce the vulnerability of infrastructure.**

- ■ Educate individuals and emergency managers about the varying impacts of winter weather on critical infrastructure based on specific meteorological and sociological parameters (e.g., time of day, day of week, urban vs. rural, surface temperature);
- ➤ Develop protocols and standards for rapid repair and restoration of critical infrastructure and other essential facilities subjected to wind, snow, and ice loads;
- ➤ Model the potential effects of severe winter weather on critical infrastructure and essential facilities in advance of storms and immediately after to predict and reduce vulnerability in the short-term and long-term;

- ✱ Develop improved engineering standards, smarter transportation systems, more resilient critical infrastructure and essential facilities in addition to cost-effective technology to ensure that these facilities maintain robust operations during severe winter weather.

GRAND CHALLENGE #5: **Assess disaster resilience.**

- ■ Develop community response, contingency, and evacuation plans based on knowledge of extreme weather events derived from long-term data analysis;
- ■ Coordinate inter-agency, detailed post-storm assessment of damage, injuries, and deaths;
- ■ Develop flexible and effective mitigation plans for transportation infrastructure and public health preparedness.

GRAND CHALLENGE #6: **Promote risk-wise behavior.**

- ■ Improve individual understanding of probabilistic forecasts through a coordinated national outreach effort;
- ■ Improve education and outreach at the individual (e.g., automated calls to those at risk), community, state, and Federal levels;
- ■ Develop a weather communication system for transportation systems (e.g., weather alerts along interstates, smart highways);
- ■ Deploy a seamless suite of reliable and accurate probabilistic winter-weather forecasts, warnings (0–12 hours), watches (12–72 hours), weekly outlooks (3–8 days), and seasonal outlooks.

Key: ■ Short Term Action (1–2 years) ➤ Medium Term Action (2–5 years) ✱ Long Term Effort (5+ years)

Expected Benefits: Creating a More Disaster-Resilient America

Fulfilling this winter storm-specific implementation plan will create a more disaster-resilient America. Specifically:

Relevant hazards are recognized and understood. Accurate regional winter weather climatologies will include probabilities of ice storms and blizzards to enhance public awareness of weather hazard risks.

Communities at risk know when a hazard event is imminent. More precise, detailed forecasting for snow, sleet and/or freezing rain in each community, neighborhood, and specific street addresses will yield better, more actionable warnings. More accurate winter weather watches and warnings can be issued with more time to prepare and mitigate.

Individuals at risk are safe from hazards. Standards and technologies will enable cost-effective, state-of-the-art winter storm resilient provisions to be adopted as part of state and local building codes and improved resilient design of transportation systems.

Disaster-resilient communities experience minimum disruption to life and economy after a hazard event has passed. Accurate, localized predictions of winter weather impacts will offer significant payoffs to maintain infrastructure and lifelines services for communities with minimal interruption.

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2. http://www.publicaffairs.noaa.gov/releases2005/jul05/noaa05-091.html

BIOGRAPHY FOR SHARON L. HAYS

Dr. Sharon L. Hays was confirmed by the Senate as Associate Director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President in late September, 2006. In this role, she serves as the OSTP Director's Deputy for Science. Dr. Hays has been at OSTP since mid-2002, serving first in OSTP's Technology Division, and later as the Chief of Staff.

Before coming to OSTP, Dr. Hays was the Staff Director of the Subcommittee on Research of the U.S. House of Representatives' Committee on Science from the beginning of the 107th Congress until August 2002. Prior to her promotion to Staff Director, Dr. Hays worked as a professional staff member, first for the Basic Research Subcommittee and subsequently for the Subcommittee on Space and Aeronautics. She first joined the Science Committee's staff in mid-1999.

Dr. Hays served as an American Association for the Advancement of Science Congressional Science Fellow in the office of Representative Vernon Ehlers between 1997 and 1999. She worked on a Science Committee project assigned to Dr. Ehlers by then-Speaker Newt Gingrich and former Science Committee Chairman F. James Sensenbrenner: to outline an updated science policy for the Nation. That effort culminated in a comprehensive Science Committee report entitled *Unlocking Our Future: Toward a New National Science Policy.*

Before coming to Capitol Hill, Dr. Hays worked as a research assistant at the University of Southern California and then attended graduate school in biochemistry at Stanford University, where she studied in the laboratory of Nobel Laureate Paul Berg and received her Ph.D. in 1997. Dr. Hays also holds a B.A. in Molecular Biology from the University of California, Berkeley.

Dr. Hays lives with her husband in Virginia, where she volunteers as a dog handler for wilderness search and rescue efforts.

Chairman WU. Thank you, Dr. Hays. Dr. Levitan, please proceed.

STATEMENT OF DR. MARC L. LEVITAN, DIRECTOR, LOUISIANA STATE UNIVERSITY HURRICANE CENTER; CHARLES P. SIESS, JR. ASSOCIATE PROFESSOR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, LOUISIANA STATE UNIVERSITY

Dr. LEVITAN. Good morning. Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to discuss with you today the impacts of windstorms.

I was asked to provide some input on several questions addressing the vulnerability of the built environment, and how that is changing research needs and windstorm hazard mitigation, recommended changes in the wind program, and technology transfer challenges.

And as mentioned in the opening statements, this year has already proven to be one of the deadliest tornado seasons in recent years. Certainly, our hurricane experience, as we have seen in just the past few years, seven of the 13 costliest hurricanes in U.S. history have occurred in just the past few years, and that trend is continuing as the population continues to move to coastal areas, as increasing urbanization occurs, and so, those trends, at the moment, while there is some positive development going on, those trends for increased damage are, unfortunately, continuing.

In terms of research needs, I point out, I think what are several key opportunities for making step change improvements, in terms of some of the longer-term activities. Understanding the wind environment of land-falling hurricanes, as we have Hurricane Dolly today making landfall in Texas. Some of my colleagues from Texas Tech University are out with instruments, similar to those pictured on the slide, making measurements of windstorms. We really don't understand what happens in the wind environment down near the ground level when the storms make landfall, and that is obviously where it affects buildings and bridges and people and things. So, that is where we need to understand that.

Computational wind engineering is an area that needs study that provides the idea that you ultimately could get a wind tunnel on your desktop, a virtual wind tunnel, where you can use new technology to study the effects of the wind for, in the design sense, on the building, without having to do the complexities of wind tunnel testing, or the simplifications required by codes.

Windstorm damage using remote sensing. In the last few years, as remote sensing capabilities have been improved, or commercially available, where you can very clearly see individual buildings, and the roof, et cetera. That provides enough level information where we could potentially get very rapid and automated damage assessments over large scales when we have these major disasters.

Performance-based design for windstorms—that is a technology in its infancy where building owners and architects and engineers would sit down at the beginning of a project, and say what is the specific performance objectives for a building, and how would I reach that. So, if I wanted a building that had no damage at all in a Category 3 hurricane, and on a Category 4 or 5, you could sustain some damage, but still be operable or reparable, the idea is you would set the design criteria so you would have a specific performance in mind for various objectives, and that technology is just in its infancy.

And finally, retrofit technologies for the existing building, since that, we have—old building code changes, and advances in the technology for new construction are wonderful, but we have so much investment in our existing infrastructure, so significant changes are needed there.

In terms of the research priorities, there is a large existing body of knowledge, and it has yet to, much of it has not been incorporated into building codes and standards, and so the initial prioritization, I believe, should be to focus in the first few years more on applied research and tech transfer for the work that is already out there, and then transitioning into more, funding later on into more of the basic research ideas that I just mentioned.

In terms of the changes to the wind program, I think it would be appropriate for NIST to become the lead agency. They have parallels to the National Earthquake Hazard Reduction Program, which they are leading, and significant expertise and experience in windstorm mitigation. And certainly, to finally form the interagency working group, and in terms of funding authorizations levels, to at least keep those consistent with the authorization levels in the existing program.

In terms of the technology transfer challenges, several of these are to use the existing research to develop new methods for assessment and design of buildings. The next two highlighted in red there, incorporating research into building codes and standards, and developing design guides and software tools. Those, I think, are the real opportunities for very rapid improvements right now, with a small investment in technology transfer, to use the existing research to improve the building codes very quickly.

Developing textbooks and curricular material for instructors, incorporating wind mitigation into curricula. So, some of these challenges on this slide indicate some that are not particularly, only dependent on funding, but they have several other criteria, in terms of education and training of construction and tradespeople, adoption and enforcement of codes is a critical challenge. It is only, again, partly dependent on funding. And then, education and training in a broader sense are critical for the public.

So, with the closing remarks, I would just say that the windstorm impacts on the U.S. are continuing to increase, and the Wind Program is really the best opportunity to provide a change in that trend, and really has the opportunity to provide a step change increase in the hazard mitigation opportunities, and really, the coordination activities between the various efforts that are even underway, are really a way to multiply the effectiveness of the existing and new activities. So, reauthorization, I think, is a critical step forward.

Thank you.

[The prepared statement of Dr. Levitan follows:]

PREPARED STATEMENT OF MARC L. LEVITAN

1. Introduction

Mr. Chairman and Members of the Subcommittee, my name is Marc Levitan and I appreciate the opportunity to address you this morning. I am Director of the Louisiana State University Hurricane Center and the Charles P. Siess, Jr. Associate Professor of Civil and Environmental Engineering at Louisiana State University. I am also the immediate past-President of the American Association for Wind Engineering (AAWE), and a member of the American Society of Civil Engineers (ASCE). I am appearing today on behalf of the Louisiana State University Hurricane Center, AAWE, and ASCE.

Louisiana State University is the flagship institution of the state, classified by the Carnegie Foundation as a Doctoral/Research-Extensive University. The university has a long history of research in hurricanes, coastal sciences and engineering. The LSU Hurricane Center was founded and approved by the Louisiana Board of Regents in the year 2000 to provide a focal point for this work, with a mission to advance the state-of-knowledge of hurricanes and their impacts on the natural, built and human environments, to stimulate interdisciplinary and collaborative research activities, to transfer new knowledge and technology to students and professionals in concerned disciplines, and to assist the state, the Nation, and world in solving hurricane-related problems. The study of wind effects on the built infrastructure and wind damage mitigation is one of the main focus areas of the LSU Hurricane Center, including: wind tunnel studies for wind effects on buildings, industrial structures and bridges; techniques for hurricane and tornado shelter assessment; evacuation and sheltering decision support tools; wind damage investigations; and participation in development of national wind loading codes and standards.

The American Association for Wind Engineering (AAWE) was originally established as the Wind Engineering Research Council in 1966 to promote and disseminate technical information in the research community. In 1983 the name was changed to American Association for Wind Engineering and incorporated as a non-profit professional organization. The multi-disciplinary field of wind engineering considers problems related to wind and associated water loads and penetrations for buildings and structures, societal impact of winds, hurricane and tornado risk assessment, cost-benefit analysis, codes and standards, dispersion of urban and industrial pollution, wind energy and urban aerodynamics.

The American Society of Civil Engineers ASCE, founded in 1852, is the country's oldest national civil engineering organization representing more than 140,000 civil engineers in private practice, government, industry and academia dedicated to the advancement of the science and profession of civil engineering. ASCE is a 501(c) (3) non-profit educational and professional society. ASCE is an American National Standards Institute (ANSI)-approved standards developer and publisher of the Minimum Design Loads for Buildings and other Structures (ASCE–7), which is referenced in the Nation's major model building codes. As part of the ASCE–7 document, engineers are provided guidance in estimating the loads resulting from wind effects on structures. Thus, ASCE is at the forefront in the development of new information for engineers regarding wind and is in a unique position to comment on the status quo and our needs for the future.

2. Vulnerability of U.S. Built Environment—and its Occupants—to Windstorm Hazards

As well documented in recent years, the damage and destruction caused by windstorms in the U.S. has continued to rise dramatically. According to the National Oceanographic and Atmospheric Administration, 2008 could be a record setting year for tornado deaths.

> *This year may set records for tornadoes and tornado-related deaths. . .. "It is only the third time since the 1974 super tornado outbreak that there have been more than 100 tornado-related deaths during a single tornado season in the U.S.," added Harold Brooks, a research meteorologist at NOAA's National Severe Storms Laboratory also in Norman. "In 1998 and 1984 there were 132 and 122 tornado-related deaths, respectively—2008 will likely equal or exceed that record." (NOAA, 2008).*

In just the past few years, the country has experienced an unprecedented level of damage due to landfalling hurricanes.

> *It is of note that the 2004 and 2005 hurricane seasons produced seven out of the nine costliest systems ever to affect the United States. (Blake et al., 2007).*

The combined cost of those seven storms was approximately $160 Billion dollars. Even after adjusting for inflation, the 2004–2005 hurricane seasons account for four of the top five costliest hurricanes in history.

The trends for rising damage are due in part to increasing population, urbanization, movement of population to areas more prone to severe windstorms, and cyclical trends in storm activity levels. While recent investigations have shown that buildings designed and constructed in accordance with the latest building codes and standards perform much better than earlier buildings in extreme winds (e.g., Gurley et al., 2006; Building Code Compliance Office, 2006), they still experienced significant damage from wind and wind-driven rain. Furthermore, since adoption of new building codes only impacts future new construction and major renovations—it will take decades before the majority of buildings in the U.S. would even get this benefit, and that assumes much more widespread education of design professionals in windstorm hazard mitigation and more widespread adoption and enforcement of the lastest codes and standards. Without significant improvements in technologies and products for retrofitting existing buildings, the windstorm vulnerability of the majority of the current building inventory will remain static.

3. Research Needed to Facilitate Wind Damage Mitigation

Basic and Applied Research Needed to Facilitate Mitigation for New and Existing Buildings

A number of recent publications have discussed big picture research needs related to windstorm hazard mitigation. Rather than revisiting those topics, this section will focus on discussion of several of the most important specific research questions and opportunities, those that have the potential to ultimately provide a significantly advance in windstorm hazard mitigation.

Wind Environment of Landfalling Hurricanes: Comparatively little is known about wind transitions from water to land and the mechanisms which cause localized higher intensity winds. Developing a greater understanding of these phenomena will lead to better estimates of maximum hurricane wind speeds, velocity profiles, and turbulence characteristics needed for building design.

Computational Wind Engineering: This technology offers the promise of a 'wind tunnel on a computer,' where details of a building and surrounding structures and terrain could all be modeled in a computational environment to provide information on wind loads and, when coupled with structural analysis programs, the response of the structure to different wind conditions.

Windstorm Damage Assessment Using Remote Sensing: This technology could potentially provide rapid and consistent damage estimates over entire windstorm impacted areas, with applications to rapid response and recovery operations, building performance observations, and validation data for damage models.

Performance-Based Design for Windstorm Hazards: Current wind load design procedures are somewhat prescriptive in that the building performance objectives are not clearly defined. The next generation of procedures is for a facility owner to identify what performance level (e.g., no damage and building is fully operational, significant damage requiring evacuation of the building but repairable) is desired for different probability windstorm events and designing the facility accordingly.

Retrofit Technologies for Wind Resistance: Although it is much easier to build wind resistance into new construction, the country has an enormous investment in existing building stock. Technologies for cost-effective retrofits to improve windstorm resistance of these buildings should be an important focus of any new research program.

Balance Between Long-Term and Short-Term Priorities

The *National Windstorm Impact Reduction Program Act of 2004* (P.L. 108–360) identifies three primary program components:

1. Understanding of Windstorms
2. Windstorm Impact Assessment
3. Windstorm Impact Reduction

In principle, the short-term priorities should be those activities that have the quickest payoff and are the most cost effective. There is a large body of research findings available right now that has not yet been translated into practical applications. The very applied research and technology transfer activities that primarily support the third program component of Windstorm Impact Reduction should therefore be given the highest initial priority. Section 5 of this Statement summarizes the main tasks required for technology transfer. Tasks 2 and 3 in that section (translation of research into improved codes and standards and design tools) will provide the most immediate returns and should have the highest initial priority. The more basic research activities, such as those discussed in the previous section, will really advance the state of knowledge and should be the focus of longer-term priorities. They should not be ignored from the start, but rather begun at a comparatively lower level and then ramped up over time.

Private Industry Research

The fragmented nature of the entire built infrastructure design and construction industry effectively precludes any industry-funded basic research, as opposed to industries like electronics, aircraft or automobile manufacturing that are dominated by a small number of global-scale corporations that must make significant basic and applied research investments to remain competitive. The modest amount of industry funding applied to wind hazard mitigation has been very applied in nature. It has created important new products and services and helped transform a few industries, but these changes generally occurred only when driven by advances in building codes and standards.

Private industry research in wind hazard mitigation has primarily taken place in the arena of product-oriented research and development, particularly in the area of products to protect building openings from windborne debris. Building code changes in Florida after Hurricane Andrew created a new market, initiating development of products to meet the impact testing requirements of that code. The most notable effect was the introduction of many new types of impact resistant windows, shutters, and screens. Significant product-oriented research and development has also taken place for wind and debris impact resistant doors, garage doors, wall systems, roof systems, and wall and roof anchoring and bracing systems. The market for all of these products has continued to expand in recent years, as more coastal areas in other states have begun to adopt and (to a lesser extent) enforce building codes that require higher wind loads and in some cases, debris impact protection.

Following several devastating tornadoes in the Midwest U.S. in the late 1990's and the well-publicized devastation caused by the Oklahoma City Tornado in May 1999, the Federal Emergency Management Agency published two milestone reports that provided guidance for design and construction of residential and community storm shelters (FEMA, 1999; FEMA, 2000). These documents, along with the National Storm Shelter Association's publication of an industry standard (NSSA, 2001), helped spur a significant product-oriented research and development for tornado shelters and helped create a market for products designed and tested to meet these technical criteria, which provided a major step forward for the fledgling storm shelter industry.

Private industry has also made significant advances in a few other areas as well, including: wind hazard, vulnerability, and risk assessment; wind loss estimation techniques, and wind tunnel testing.

4. National Windstorm Impact Reduction Program Implementation

Implementation and Funding of NWIRP

The National Windstorm Impact Reduction Program (NWIRP) was created through the *National Windstorm Impact Reduction Program Act of 2004* (P.L. 108–360). The objective of the NWIRP is to achieve measurable reductions in losses of life and property due to windstorms. The objective is to be reached through a coordinated, federally-led effort to first, assess and prioritize research, technology transfer, and education needs, and second, to conduct wind hazard mitigation activities in context of the overall objectives of the Program.

Unfortunately, funding for the NWIRP was never appropriated, so little has been achieved towards meeting the program objectives. The federal agencies involved in the program (NSF, FEMA, NIST, and NOAA) report that they have undertaken a modest level of activities in areas related to or consistent with the aims of the NWIRP. However, given funding constraints, the overarching planning and coordination activities are still missing and the agencies have not been able to significantly increase their level of wind hazard mitigation activities as authorized by the NWIRP.

Recommended Changes to NWIRP Legislation

As coordination of NWIRP activities is critical to maximizing the effectiveness of the existing and proposed wind hazard mitigation efforts, **the National Institute of Standards and Technology (NIST) should be designated as the lead agency.** The NWIRP has strong parallels to the successful National Earthquake Hazards Reduction Program (NEHRP), for which NIST is the lead agency. Additionally, the topic area and the required mix of basic and applied research and technology transfer activities makes NIST the logical choice. They have significant expertise and experience in wind engineering research and technology transfer and research program management.

The continued escalation of loss of life and property due to windstorms, with several records being set in just the 2004–2008 time period, highlights that NWIRP is needed now more than ever. **Authorized funding levels for the first year of the Program should therefore be at least consistent with the currently authorized amounts. Funding should ramp up significantly in the following years,** as initial planning and prioritization activities are completed and funding of wind hazard mitigation project activities can most effectively expand.

5. Challenges of Transferring Research Results from the Laboratory into Practice

The challenges of transferring windstorm damage mitigation findings are numerous, but many can be addressed comparatively easily if adequate funding is provided. Others include tough hurdles unrelated to financial resources. The main technology transfer tasks are summarized in the following list.

1. Using basic research findings to create new assessment, analysis, and design procedures for building components, systems, and entire structures
2. Incorporating wind engineering research findings into building codes and standards
3. Developing wind design guides, software tools, and other products for practicing professionals
4. Developing textbooks and other materials for use in undergraduate and graduate education in the fields of engineering, architecture, construction, and building science
5. Incorporating windstorm hazard mitigation into engineering, architecture, construction, and building science curricula
6. Education and training of building construction tradespeople and laborers
7. Adoption of strong and current building codes by municipalities and states
8. Enforcement of building codes
9. Education and training of persons working in the fields of insurance, real estate, mortgage lending, emergency management, and elected and appointed officials
10. Consumer education

Tasks 1–4 are reasonably straightforward and progress is primarily dependent on availability of funding. Incorporation of windstorm hazard mitigation into the formal educational programs of design professionals (Task 5) will be made easier by the results of tasks 2–4, but still faces two hurdles. Most of the professors are not knowledgeable in this field, and the current trend at universities is for cutting the number of credit hours required for degrees, making it more difficult to add new material. These challenges must however be met if we are to begin graduating design professionals who understand the theory and practice of windstorm hazard mitigation. Education and training of tradespeople and laborers (Task 6) on how to install critical components such as wind bracing or roofing shingles or hurricane shutters is obviously important but difficult in an industry where there is a transient workforce that often has language barriers.

Adoption of building codes is often a political hot potato. In recent years some states and municipalities have adopted strong model building codes but stripped out the windborne debris protection requirements in coastal areas, gutting one of the most critical components of the code. There are still many areas of the country that have not adopted building codes or their codes are very outdated. Enforcement is even more problematical, particularly for rural and poorer municipalities where funding and training of building department staff is often inadequate.

Tasks 9 and 10 are critical in order to develop public understanding of the need for and benefits of windstorm hazard mitigation through building codes and code plus alternatives. The areas that have experienced repeated devastating windstorms, such as South Florida and Oklahoma City, seem to have built a higher level of public awareness of these issues and understand that building code adoption and enforcement have direct implications for life safety, property damage, cost of construction, cost and availability of insurance, and resale value. Windstorm related research, building code changes, and insurance are front page news in those communities. It's much more difficult to raise significant awareness of these issues in communities that have not had a wind-related disaster in recent years.

6. Closing Remarks

The unparalleled devastation in the U.S. caused by windstorms in just the last four years, with damage costs approaching $200 billion, makes it clear that something must be done. The funding levels authorized in the existing NWIRP ($25 million per year) are trivial with respect to the average damage costs per year. If the program were to produce even the smallest of improvements in wind hazard mitigation, the NWIRP would pay for itself many times over. A fully-funded NWIRP would in actuality provide a step change improvement in wind damage reduction, which would over time significantly reduce the U.S. vulnerability to severe windstorms.

Reauthorization of the National Windstorm Impact Reduction Program is a critical step in the process, but ultimately of little value unless funds are appropriated to make the Program a reality. As annualized windstorm costs continue to skyrocket, this country can no longer afford to ignore the problem. An investment must be made in windstorm hazard mitigation and the National Windstorm Impact Reduction Program is the way to get it done.

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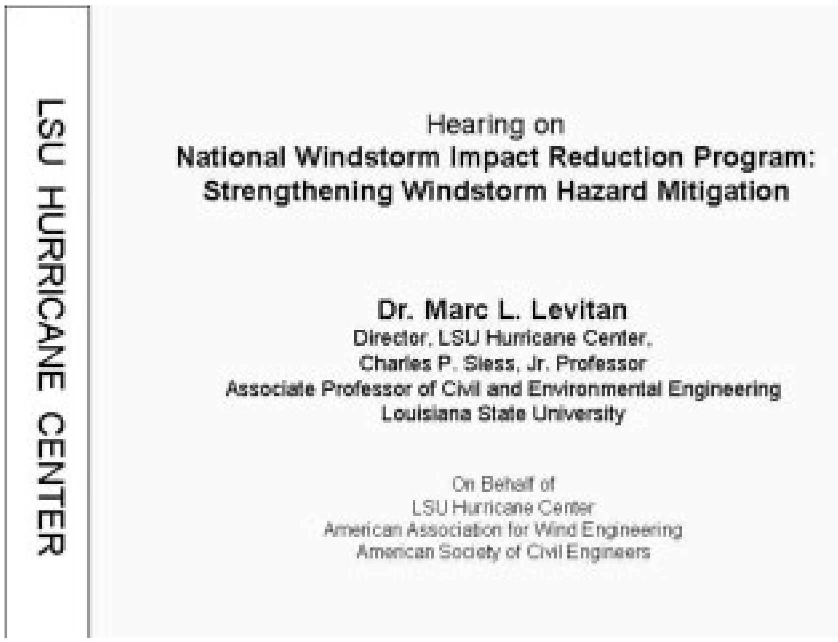
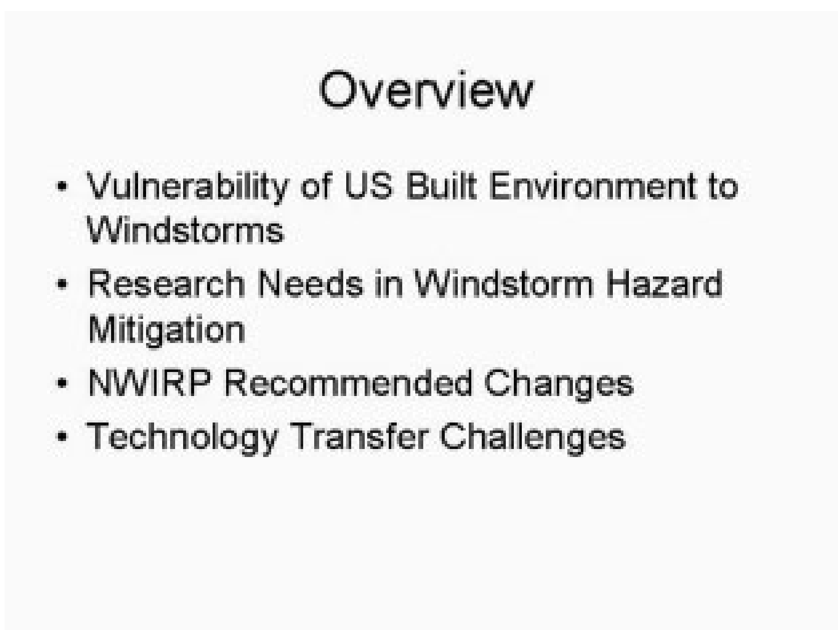




US Vulnerability to Windstorms

- Windstorm damage costs escalating
- 2008 one of deadliest tornado seasons
- 'Costs' are much more than casualty figures and direct dollar figures
- Negative impacts on
  - Millions of families
  - Whole communities destroyed
  - Energy Security of the Nation

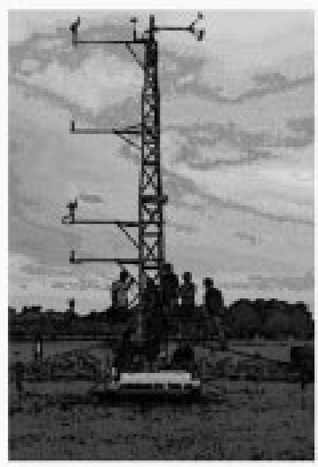
Costliest US Hurricanes (2006 Dollars)

Rank	Hurricane	Year	Damage ($B)
1	Katrina (LA/MS/FL)	2005	85
2	Andrew (FL/LA)	1992	48
3	Wilma (FL)	2004	22
4	Charley (FL)	2004	16
5	Ivan (AL/FL)	2004	15
6	Hugo (SC)	1989	13
7	Agnes (FL/NE US)	1972	12
8	Betsy (FL/LA)	1965	12
9	Rita (LA/TX)	2005	12
10	Camille (MS/LS/VA)	1969	10
11	Frances (FL)	2004	10
12	Diane (NE US)	1955	8
13	Jeanne (FL)	2004	8

(Source - NOAA)

Research Needs

- Wind Environment of Landfalling Hurricanes
- Computational Wind Engineering
  - 'Wind tunnel' on a computer
- Windstorm Damage Assessment Using Remote Sensing
- Performance-Based Design for Windstorm Hazards
- Retrofit Technologies for Wind Resistance



Research Priorities

- Existing body of research knowledge that has not yet been incorporated into building codes, standards, and design and construction practices
- Initial prioritization to applied research and tech transfer
  - Provides most immediate results
- Ramp up basic research funding

NWIRP

- NIST should become lead agency
  - Program has parallels to NEHRP
  - Expertise and experience in windstorm mitigation research
- Form Interagency Working Group and National Advisory Committee
- Funding Authorizations
  - Initially consistent with current levels
  - Ramp up over time as research capacity increases


Technology Transfer Challenges
Progress Primarily Dependent on Funding
• Using research findings to create new assessment, analysis, and design procedures for building components, systems, and entire structures
• Incorporating research into building codes and standards
• Developing design guides, software tools, and other products for practicing professionals
• Developing textbooks and curricular materials for engineering, architecture, construction, and building science


Technology Transfer Challenges
Progress Only Partially Dependent on Funding
• Incorporating wind mitigation into engineering, architecture, construction, and building science curricula
• Education/training of construction tradespeople and laborers
• Adoption of strong and current building codes by municipalities and states
• Enforcement of building codes
• Education/training for insurance, real estate, mortgage lending, emergency management, and elected and appointed officials
• Consumer education

BIOGRAPHY FOR MARC L. LEVITAN

Dr. Marc Levitan has been actively engaged in wind and hurricane engineering research, practice, and education for 20 years. His areas of research include assessment, analysis and design of structures for hurricane resistance, including wind and hurricane effects on critical and essential facilities, storm shelters, and industrial and petrochemical structures. He is the founding Director of the LSU Hurricane Center and co-founder of the LSU Wind Tunnel Laboratory. He chairs the ICC committee developing a national standard for the design and construction of storm shelters, and also chairs the ASCE committee developing wind loading guidelines for the petrochemical industry. Other national service includes the ASCE 7 Main Committee and Wind Load Subcommittee, the ASCE Aerodynamics Committee, and the ASCE Wind Effects Committee. Dr. Levitan also chairs the ASCE National Infrastructure and Research Policy Committee. He is Past-President of the American Association for Wind Engineering and chaired the 10th Americas Conference on Wind Engineering in Baton Rouge in 2005. The academic pursuits of Dr. Levitan are structural engineering, wind engineering, and hurricane engineering. Prior to joining LSU, he spent five years as the first Managing Director of the Wind Engineering Research Field Laboratory at Texas Tech University.

Chairman WU. Thank you, Dr. Levitan. Ms. Chapman-Henderson, please proceed.

STATEMENT OF MS. LESLIE CHAPMAN–HENDERSON, PRESIDENT AND CEO, FEDERAL ALLIANCE FOR SAFE HOME, INC.—FLASH®

Ms. CHAPMAN-HENDERSON. Thank you, Mr. Chairman and Committee Members.

My name is Leslie Chapman-Henderson, and I am here today representing the Federal Alliance for Safe Homes. We are a partnership of more than 100 public, private, and nonprofit organizations and leaders who have dedicated the past 10 years to making America a more disaster-resistant nation. Our mission is to "strengthen homes and safeguard families" from disasters of all kinds, including earthquakes, floods, hail, hurricanes, lightning, tornadoes, and wildfire.

We view our work as part of a larger social movement to establish disaster safety as a public value in this country. Our goal is to create widespread homeowner demand for safer, better built homes, much like the highway safety movement, which succeeded in creating American demand for safe, well-built vehicles. Just as the highway safety movement has saved lives on our roads, the disaster safety movement can and does save lives, homes, and buildings in catastrophic events. We believe that the United States built environment is highly vulnerable to windstorm hazards, and that is increasing.

We perceive that the greatest challenge in strengthening new or existing buildings is a lack of information, and a lack of knowledge transfer between the many stakeholders that need to understand windstorm prevention options. After hurricanes and tornadoes, we frequently meet homeowners who are very frustrated to learn that a mere handful of additional nails may have made a difference in keeping their roof in place.

We believe that one of the best means of solving this problem is to put in place a system of state-of-the-art, consistently enforced, model building codes that incorporate all research findings on a timely basis, but these have to be put in place before windstorms strike. This would overcome the often lost opportunity to rebuild damaged communities in a stronger way, because improving codes after the storm can happen too late to affect the quality of the new built environment.

If we rebuild without the advantage of new techniques and mitigation, we perpetuate a cycle of build, destroy, rebuild, that our organization and movement is working to break. We have found that effective mechanisms for convincing stakeholders to adopt wind mitigation measures include a combination of public awareness, market demand, innovative mitigation programs, model codes, professional education and, of course, research.

A few innovative model programs are the My Safe Florida Home and South Carolina Safe Home Initiatives. These programs provide wind mitigation home inspections and matching grants for home hardening and retrofitting. These efforts help homeowners understand the relative strengths and weaknesses of their homes by assigning a ranking on a one to 100 scale. They then provide matching funds to help offset the costs of retrofitting or hardening.

Understanding and communicating the linkage between strong buildings and sound economics is a powerful public motivator as well. Let us take Texas, for example, in light of what has happened there in the last 48 hours. Catastrophe models tell us that the average annual expected insured losses from hurricanes for single family homes in Texas are approximately $932 million per year, or nearly $1 billion. If we could retrofit the entire stock of homes there, using modern building codes, that loss expectation would drop by 40 percent, to $562 million. Moreover, if we rebuilt the entire housing stock to a slightly code plus standard, that annual expected loss would drop 78 percent to $206 million per year.

Another key area of improvement in building practices that we support, of course, is to increase funding for research and innovation. We need to better understand how and why buildings survive or fail in windstorms, and our academic partners still do not have all the answers. We believe that FEMA and the National Weather Service do an excellent job of communicating the importance of mitigation as a priority. However, by its nature, the information has to be delivered at the State, and especially at the local level.

We strongly urge you—we strongly support the National Windstorm Impact Reduction Program, and strongly encourage the reauthorization, with investment of additional resources. We believe the three most important areas to emphasize include activities to enhance the understanding of windstorm research, development of improved outreach and implementation mechanisms, and outreach and information dissemination related to cost-effective and affordable construction techniques to all audiences. With regard to implementation, we believe that the program should establish a singular guiding principle to ensure that program outcomes and discoveries are widely shared with the general public.

I want to thank you for the opportunity to join you today, for all you are doing to help protect Americans from the devastating effects of windstorms, and for helping homeowners in this country understand that luck should not be their first line of defense when they confront natural disaster threats.

[The prepared statement of Ms. Chapman-Henderson follows:]

PREPARED STATEMENT OF LESLIE CHAPMAN-HENDERSON

Introduction

Thank you Mr. Chairman and Committee Members.

My name is Leslie Chapman-Henderson and I am here today representing the Federal Alliance for Safe Homes. We are a partnership of more than 100 public, private and nonprofit organizations and leaders who have dedicated the past ten years to making America a more disaster-resistant nation. Our mission is to "strengthen homes and safeguard families" from disasters of all kinds, including earthquakes, floods, hail, hurricanes, lightning, tornadoes and wildfires.

The Federal Alliance for Safe Homes helps reduce impacts from catastrophic losses like windstorms by providing the public with accurate and timely information on how to make homes more disaster-resistant—either at the time of construction or with post-construction hardening or retrofitting techniques. We want consumers to understand that they can protect their property, and "luck" is not their best tool when they confront natural disaster threats.

We view our work as part of a larger social movement to establish disaster safety as a public value in this country. This is a movement that supports a built environment strong enough to reasonably resist and survive natural disaster threats. We specifically focus on mitigation and the collective work undertaken beforehand to prevent or lessen impacts of hurricanes and other threats.

Our goal is to create widespread homeowner demand for safer, better-built homes. We modeled this approach after the highway safety movement, which succeeded in creating American demand for safe, well-built vehicles with seat belts and air bags. Just as the highway safety movement has saved lives on our roads, the disaster safety movement will reduce losses from catastrophic events. We recognize the following elements as essential to the establishment of the disaster safety movement:

- Building codes that are enacted and enforced
    - Applied to new construction, rehabilitated construction and restored construction
- Financial incentives
    - Including banking, insurance, real estate, tax
- Mitigation public policy

  - Inspection and matching grant programs
- Public awareness
- Professional education
  - Architecture, construction, engineering
- Research and innovation

Our typical activities include public awareness campaigns featuring free resource and referral services through a toll-free telephone hotline and the *www.flash.org* website, integrated multi-media campaigns, professional education programs and extensive public outreach. Below is a sampling of our initiatives:

- *Blueprint for Safety*®—An award-winning curriculum for contractors, design professionals and home inspectors featuring training on disaster-resistant construction techniques. Blueprint recommendations are referenced as the basis for mitigation policies and programs enacted in several states, including Florida, Louisiana, Mississippi and South Carolina.
- *The Tale of Two Houses*—A motivational video story of two neighboring families and homes affected by 2004's Hurricane Charley that demonstrates dramatically different building performance and outcomes based on the different building practices used. The Tale of Two Houses program inspired a season of nationally syndicated television shows and joint work with home improvement guru Bob Vila.
- *Turn Around—Don't Drown*—A jointly owned public awareness life safety campaign with the National Weather Service that helps raise awareness of the risks associated with walking or driving into moving water. The slogan is in widespread use by broadcast meteorologists, forecasters and others. Outdoor advertising campaigns are focused at the State level and are in place in Florida, Nevada, Texas and other states.
- *StormStruck: A Tale of Two Homes*™ ... presented by the Federal Alliance for Safe Homes—StormStruck is an interactive "edu-tainment" experience that will open in late summer of 2008 at Epcot at the Walt Disney World Resort in Florida. The high tech simulated storm experience will combine fun with game-based learning to provide more than four million annual guests to Epcot with information on how to protect their homes and families from severe weather.

While our organizational focus is solely on residential structures, my comments today will be relevant for some aspects of commercial structures as well.

Commentary/Response to Committee Questions

Question #1—How vulnerable is the U.S. built environment—and its occupants—to windstorm hazards? Has this vulnerability increased or decreased in recent years?

We believe that the U.S. built environment is highly vulnerable to windstorm hazards, and the vulnerability is increasing. There are various ways to characterize the level and demonstrate the increase, including:

A) *Coastal Population Growth.* According to the U.S. Census Bureau, as of July 1, 2007, 35.3 million people lived in areas of the United States *most* threatened by hurricanes.[1] These areas are defined as the coastal portions of Texas through North Carolina and represent approximately 12 percent of the U.S. population. This figure represents an increase from the 1950 level of 10.2 million, which represented seven percent of the U.S. population. Florida alone represents six percent of the current coastal population.

Three of the 20 most populous metro areas from 2006 to 2007 were within Atlantic or Gulf coastal areas from North Carolina to Texas.[2] These areas are:

- Houston-Baytown-Sugar Land, Texas (sixth)
- Miami-Fort Lauderdale-Miami Beach, Fla. (seventh)
- Tampa-St. Petersburg-Clearwater, Fla. (19th)

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[1] Source: Population Estimates *http://www.census.gov/popest/estimates.php*

[2] Source: *http://www.census.gov/Press-release/www/releases/archives/population/011671.html*

Note: Coastal counties include those with at least 15 percent of their total land area within the Nation's coastal watershed.[3]

B) *Historic Losses*[4] *(United States).* Disaster losses tell a compelling picture of our economic and societal vulnerability to windstorms. From 1987 to 2006 the inflation-adjusted, insured losses break down as follows:

- $297.3 billion—total disaster losses
- $137.7 billion, or 46.3 percent—tropical cyclone losses
- $77.3 billion, or 26 percent—tornado losses
- $19.1 billion, or 6.4 percent—earthquake losses

Seven of the 10 most expensive hurricanes in U.S. history occurred between August 2004 and October 2005.

C) *Today's Insured Values (Sample: Florida).*

- 4.5 million single family homes
- $1.8 trillion in residential property
- $1.0 trillion in commercial property

D) *Coastal Construction (Sample: Galveston, Texas).*

- More than *$2.3 billion in* residential, commercial and public construction was underway in 2007[5]
- More than 6,500 residential units under construction
- Mostly condos, including towers up to 27 stories high
- One Centex Homes development—2,300 condos and houses on 1,000 acres
- Galveston is the site of the deadliest natural disaster in U.S. history
- At least 8,000 people were killed in a 1900 hurricane
- 3,600 homes were destroyed

The current seawall in Galveston is only 15.6 ft. high; Katrina's storm surge was nearly 30 feet. Insured losses today from a repeat of the 1900 storm would exceed $21 billion, and it would become the 3rd most expensive hurricane in U.S. history (after Katrina and Andrew).

E) *Attributes of the Built Environment.* Vulnerability will continue to increase due to a variety of economic and other factors, including the aging of our built environment, the percentage of the built environment constructed without use of model building codes, and the increased cost of new construction.

Question #2a—What are the challenges in implementing improvements to new or existing buildings?

The greatest challenge in implementing improvements to new or existing buildings is a continuous breakdown in communication and knowledge transfer between homeowners, home builders and policy-makers. During years of post-storm interviews and damage investigations, we meet homeowners who are frustrated to learn that a mere handful of additional nails may have made a difference in keeping their roofs on during a hurricane, especially since loss of roof covering and roof sheathing failure during windstorms is typically where a total loss of structure and contents begins.

In-place and intact enactment of model building codes with requisite code enforcement infrastructure before hurricanes strike is the best means of overcoming this lost opportunity to rebuild damaged communities in a stronger way. While new codes can only impact approximately two percent of the built environment in any non-disaster year, that percentage can increase dramatically in a post-storm rebuilding period.

Unfortunately, many of the rebuilding efforts during the post-2004 and 2005 hurricanes failed to include new, uniform roofing standards requiring enhanced nailing and installation of secondary water barriers. This represents a tremendous lost op-

[3] Source <*http://www.census.gov/geo/landview/lv6help/coastal_cty.pdf*>

[4] Source: Insurance Information Institute—Presentation to the National Hurricane Conference—*http://server.iii.org/yy_obj_data/binary/784319_1_0/nhc2008.pdf*

[5] Source: Insurance Information Institute from "A Texas-Sized Hunger for Gulf Coast Homes," *New York Times,* March 18, 2007 and *www.1900storm.com* and *www.twia.org* accessed July 9, 2007.

portunity and perpetuates the cycle of “build-destroy-rebuild” that our organization and movement is working to break.

Furthermore, while outstanding progress is under way by the International Code Council and others in increasing model code adoption at the State levels, the model code can still be undermined, weakened or adversely amended upon adoption at the local level. We are concerned that many coastal, windstorm-exposed communities have adopted the 2006 International Residential Code, but also inserted provisions that remove requirements for protecting windows with code-approved shutters or other opening protection.

We believe it is well-established that protecting openings like windows is a key windstorm damage prevention practice.

Question #2b—What has FLASH found to be effective mechanisms for convincing property owners and builders to adopt wind hazard mitigation measures?

Like the highway safety movement, success relies on a combination of regulation, enforcement and education.

Intact enactment of model building codes is a vital first step, and we should reward local communities that adopt model codes by linking enhanced federal, pre-disaster mitigation dollars to the strength and enforcement record of the State and local building codes.

Communication and education are also essential. FLASH has found that the most effective ways to deliver relevant information to the public, policy-makers and affected trades and professions are:

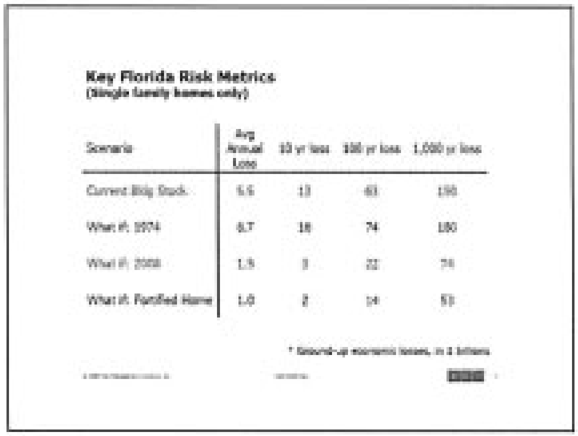
1. through news media outreach that focuses on specific storm experiences of real families,
2. by creating simple, clear and actionable “how to” information to empower consumers to ask for specific, prescriptive constructive practices at the time of building or rebuilding, and
3. by participating and serving on relevant public policy forums that create and recommend model programs.

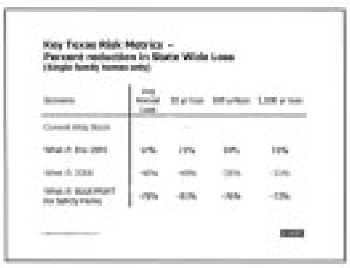
Two such model programs at the State level are the My Safe Florida and South Carolina Safe Home initiatives for residential structures. These programs provide wind mitigation home inspections and matching grants for home hardening and retrofitting activities. These efforts help homeowners understand the relative strengths and weakness of their homes, and then provide matching funds to help offset the cost of retrofitting or hardening those homes.

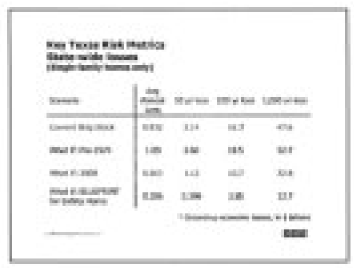
Conservatively derived measurements of the value of mitigation are also essential tools for delivering compelling mitigation improvements to the public and policy leaders. Consider these findings from an independent study by the National Institute of Building Sciences:

> Mitigation provided a return on investment of up to four-to-one. A 10-year snapshot of FEMA mitigation grants and projects found:
>
> Reduced human losses (death, injuries and homelessness)
>
> - Reduced direct property damage
> - Reduced direct business interruption loss
> - Reduced indirect business losses
> - Reduced non-market damage
> - Reduced cost of emergency response
>
> (Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities, National Institute of Building Sciences, December 2005, accessed at *http://www.nibs.org/MMC/mmcactiv5.html*)

Modeling the strength of existing building stock based on the historic building code practices can also provide a compelling case for implementing windstorm mitigation. The tables below illustrate some relevant examples:







Question #3a—Where do improvements need to be made in building practices and our ability to mitigate wind damage to structures and communities?

- Increase funding for research and innovation in building structure performance

When examining building performance post-storm, we need to understand how and why buildings survived or failed. Our academic partners still do not have all the answers to understanding wind and wind-driven rain effects on buildings, and the financial resources for this research seem inconsistently distributed and difficult to sustain on an ongoing basis. The resources dedicated to research on storm effects are greatly out-paced by research spending on earthquake hazards.

- Accelerate adoption of new construction technology findings into model building codes

The code development process is understandably deliberate, however, it often takes years to incorporate to new findings into model codes. As a result, homes and buildings continue to be built without the benefit of expensive and deadly lessons learned post-disaster.

Question #3b—How well do agencies at all levels of government advocate and educate on the importance of wind hazard mitigation measures?

We believe that federal agencies like FEMA and the National Weather Service do an excellent job of communicating the importance of mitigation as a thematic priority. However, by its nature the specific mitigation information and professional training is delivered at the State and local levels. It is our observation that Florida, Louisiana and South Carolina are the most active states in terms of mitigation outreach, education and training.

A novel concept that is in use in Florida as part of the My Safe Florida Home program is the Hurricane Resistance Rating Scale that ranks homes on a zero to 100 scale on the basis of its wind-resistant features, including roof shape, presence of opening protection, construction method, etc. This concept could be adapted to a national model scale and be incorporated into the home construction industry in all windstorm exposed states, including the so-called "Tornado Alley." The scale could help revolutionize consumers' understanding of the wind hazard, much like Energy Star revolutionized society's perception and value for energy savings.

Question #4—Please comment on the implementation of NWIRP and the level of federal funding for wind hazard mitigation R&D. Looking toward the reauthorization of the program, what do you feel are the three most important priorities and what changes would you suggest for the legislation?

We strongly support all aspects of the National Windstorm Impact Reduction Program and strongly encourage the reauthorization with additional investment of resources. We offer the following priorities based on our belief that the private sector can augment the program's efforts with significant resources.

- Improved understanding of windstorms
  - Activities to enhance the understanding of windstorms shall include research to improve knowledge of and data collection on the impact of severe wind on buildings, structures, and infrastructure. *Highest Priority*
- Windstorm impact assessment
  - Research, development, and technology transfer to improve loss estimation and risk assessment systems; *Low Priority*
  - Research, development, and technology transfer to improve simulation and computational modeling of windstorm impacts. *Medium Prioriyy*
- Windstorm impact reduction
  - Development of improved outreach and implementation mechanisms to translate existing information and research findings into cost-effective and affordable practices for design and construction professionals, and State and local officials; *Highest Priority*
  - Development of cost-effective and affordable windstorm-resistant systems, structures, and materials for use in new construction and retrofit of existing construction; *High Priority*
  - Outreach and information dissemination related to cost-effective and affordable construction techniques, loss estimation and risk assessment methodologies, and other pertinent information regarding windstorm phenomena to federal, State, and local officials, the construction industry, and the general public. *Highest Priority*

Our one implementation recommendation is that the program establish a singular guiding principle for all program outcomes as follows: "Any and all program findings, materials and information shall be communicated, shared, widely promoted and accessible to the general public with a special emphasis on reaching and targeting home buyers, homeowners, home builders and public policy-makers."

It is our firm belief that, like highway safety, the knowledgeable, empowered consumer has the most capacity to move disaster safety and windstorm mitigation forward. The essential tool they require to do is knowledge of the definition of a strong, wind-resistant home backed by a system of building codes that ensure optimal, future construction practices. We can and should continue to improve on all areas of focus identified in the National Windstorm Impact Reduction Program; however, the stronger we make our built environment, the more opportunities our citizens will have to safely shelter-in-place outside of flood-prone areas.

Biography for Leslie Chapman-Henderson

Leslie Chapman-Henderson is President/CEO of the Federal Alliance for Safe Homes, Inc.—FLASH®, a national, non-profit corporation founded in 1998 by a collaborative of non-profit, private and public organizations dedicated to strengthening homes and safeguarding families from disaster. Today, FLASH is the fastest growing disaster safety education organization in the United States with more than 90 partners, including FEMA, Georgia Pacific, Institute for Business & Home Safety, International Code Council, Mercedes Homes, NeighborWorks, NOAA, South Carolina Insurance Department, State Farm Insurance Companies, Texas Department of

Insurance, Texas Tech Wind Science & Engineering, The Home Depot and Home Depot Foundation, University of Florida, and USAA.

Ms. Chapman-Henderson and FLASH have championed the cause of code-plus construction methods through the creation of Blueprint for Safety® (Blueprint), an educational program for home builders, homeowners and design professionals on disaster-resistant construction techniques.

Among Ms. Chapman-Henderson's civic, community and professional awards are the 2008 National Hurricane Conference Outstanding Achievement in Mitigation Award, 2008 Governor's Hurricane Conference Corporate Award, 2006 Texas Silver Spur Award for Public Education Excellence, 2006 Governor's Hurricane Conference Public Information/Education Award, 2005 National Hurricane Conference Outstanding Achievement in Public Awareness Award, 2005 National Weather Association Walter J. Bennett Public Service Award, 2005 NOAA Environmental Hero Award, 2002 National Hurricane Conference Outstanding Achievement in Mitigation Award, 2002 FEMA Special Recognition Award, 2002 Florida Fire Chiefs Association Excellence in Community and Public Education Award, 2002 Florida Emergency Preparedness Association Corporate Award, and 2001 Governors Hurricane Conference Public Education Award.

Additional award-winning FLASH outreach projects include two seasons of episodes with the nationally-syndicated programs *Bob Vila* and *Home Again with Bob Vila;* a one-hour, nationally televised multi-hazard PBS Special entitled, *Blueprint for Safety . . . Disaster-resistant Homes;* and "A Tale of Two Houses," a multi-media awareness campaign, show-casing code and code-plus construction success stories.

Ms. Chapman-Henderson currently serves as co-chair of the legislatively-created My Safe Florida Home Advisory Council. Her past service includes consumer representative and chair for the Florida Hurricane Catastrophe Fund Advisory Council under Governor Charlie Crist and former Governor Jeb Bush, guest lecturer at the University of Florida—School of Construction and one of the Florida representatives to the Federal Communications Commission WARN Committee. She was recently elected as a board trustee of the Florida International University—International Hurricane Research Center.

Other past service includes trustee for the Florida Fire and Emergency Services Foundation; consumer representative to the Louisiana Uniform Building Code Task Force; consumer representative and Vice Chair on the 2005 Florida Legislative Task Force on Long-Term Solutions for Florida's Hurricane Insurance Market; and insurance consumer representative to the 2006 Property and Casualty Insurance Reform Committee chaired by former Lt. Governor Toni Jennings.

She has a Bachelor's degree from the University of Florida, resides in Tallahassee and is married to Robert Henderson.

DISCUSSION

Chairman WU. Thank you very much, Ms. Chapman-Henderson. We have come to the questions and answers portion of this hearing, and at this point, we open for our first round of questions, and I recognize myself for an opening five minutes.

I would like to ask Dr. Levitan and Ms. Chapman-Henderson to help characterize the OSTP and the general federal implementation of the National Windstorm Impact Reduction Program. How have, how is the OSTP, and how have the agencies done thus far, and what needs to be worked on to improve this program going forward?

Dr. LEVITAN. Mr. Chairman, I think, and as you pointed out in your opening statement, there has been, progress has been limited, and much of that has to do with the funding issue. And the agencies each have their own tasks, and have reported that they are working on wind hazard, various wind hazard mitigation programs, but at least from my perspective, and where I can see that, again, the coordination activities, so far, have been somewhat limited, and perhaps, the nature of the problem is the funding restrictions.

Chairman WU. When you say somewhat limited, are you being polite about that?

Dr. LEVITAN. Yes. Also, again, my nature, and from where I sit, and I am somewhat on the outside of those activities, and I, the information that I get, oftentimes, is you know, from reports. I am not here in Washington to attend all the meetings.

Chairman WU. Ms. Chapman-Henderson.

Ms. CHAPMAN-HENDERSON. Thank you, Mr. Chairman. I think one of the most valuable activities we have participated in, probably the main activity, is participating in the post-disaster investigations, and the willingness of FEMA to coordinate those, and bring us in, so that we can speed that information to the consumers, has been incredible. In 2004, we participated, and 2005, in fact, we are looking at possibly joining a Midwest flooding investigation team that is going to go out.

Because so often, I think our greatest challenge is the time it takes to take in the information, putting it into the building code cycle, which is more than three years, you know, frequently. The storms aren't going to wait, and that is one of the greatest challenges here, is we have to possibly speed up the sharing of information, and get it to, you know, into either the codes or, on a market basis, to homeowners, so they can make those choices ahead of time.

Chairman WU. Ms. Chapman-Henderson, during your testimony, you mentioned that it is important to get out ahead of the cycle, so that the FEMA advice doesn't come so late that the building codes are changed, and we get into a cycle of build——

Ms. CHAPMAN-HENDERSON. Destroy.

Chairman WU.—destroy, rebuild, destroy. Have we been shortening that cycle, or is that still a problem?

Ms. CHAPMAN-HENDERSON. It is still a problem. And one of the biggest challenges is, while the model codes are being developed, incorporating new learning and science and innovation, it is still a very slow and arduous process, but those model codes are adopted at the State level. They still have to carry through and be adopted at the local level, and we have issues across the country where, at the local level, when the model codes are adopted, adverse measures, chapters, amendments, and essentially, sometimes removing the engineering behind the wind science, are put in place, and the net effect is a weakening of the code that is put there, so it not only takes a long time to get the new codes, but it is important to preserve the quality of the model code when it gets all the way down to the homeowner. That doesn't happen today.

Chairman WU. Let me circle back in a different period of questions, about the federal role in helping disseminate that information, and getting it all the way to the ground level. Dr. Hays, I want to give you an opportunity to respond to the concerns that I expressed, and I think some of the witnesses expressed, about the level of activity that OSTP and the other agencies have engaged in, the level of coordination. It is my understanding that the Administration has simply not asked for any adequate level of funding for this particular program.

Dr. HAYS. Thank you, Mr. Chairman.

Addressing a couple of questions, I think, that you have on coordination funding, et cetera. With respect to funding, obviously, funding decisions are made within the different agencies that participate in the program. As you know, as this committee well knows, those agencies face significant challenges in prioritizing different areas of research, so not just windstorm research, related to other kinds of hazards research, but all hazards research related to everything else within their domain. So, I think the agencies have developed budgets that——

Chairman WU. Since my time is running out, what I hear you going toward is that this set of efforts simply has not come to the top of the priority list, or close enough to the top of the priority list thus far.

Dr. HAYS. I think agencies have placed a high priority on this research. I think it is important to, when we are talking about measuring coordination, which is a very abstract thing to measure, I tend to think in terms of measuring results, and keeping in mind that this program, while it has only been authorized for several years, that these programs within the agencies have existed for many years. I think there are a number of demonstrable results that have been achieved in terms of windstorm R&D.

Track forecast accuracy has been improved by 50 percent. That has led to what used to be only three day forecasts, we now have five day out forecasts that are as accurate as the three day out forecasts. The hurricane warning areas have shrunk. Those have profound implications, not just for loss of life, but also for economic implications associated with evacuations and so forth.

Similar increases in tornado warning research has led to increased warning times for tornadoes, from six minutes to 11 minutes, just between 1994 and 2002. So, I think there are a lot of things that we can point to that have been very positive, and that the agencies involved in this program are largely responsible for their research.

Chairman WU. Well, thank you, Dr. Hays. My time has expired, but I just want to point out that some of this National Weather Service, some of these meteorological capabilities are outside of this particular program, I am concerned about some of the building code issues, and some of the existing technology transfer issues that apparently have not been performed, and it has been raised by some of the written and oral testimony of the other witnesses.

But we will circle back on that, and at this point, I would like to recognize Dr. Gingrey for five minutes.

Mr. GINGREY. Mr. Chairman, thank you, and I am sure some of our questions will overlap to some extent, but I did want to ask all the witnesses, let us end with Dr. Hays, and start with Ms. Chapman-Henderson, how would you characterize the level of cooperation between the different federal agencies that are currently engaged in windstorm research?

I want to know if you have any specific suggestions that would improve your institution's interaction with the interagency research efforts as they currently exist. I know there are funding problems. Dr. Levitan and others have mentioned that, and that is a problem, of course, but do you think the R&D focus of each agency is appropriate, and are they trying to cooperate and make this program better?

Ms. CHAPMAN-HENDERSON. Well, I don't want to opine on things I don't have specific knowledge of, and we work mostly with the

National Weather Service on public education efforts, and of course, FEMA on mitigation, so I haven't had a lot of experience with the other agencies that have the role in coordination here. But I think the measure of all of this is what, which, or if any of the outcomes make it into use, either through the building codes, or through market-based knowledge that can be incorporated, and I think that there has been some tremendous progress, as was mentioned. Forecasting at the Weather Service, evacuation times, you know, have been—and that is critical. But I think because there is progress there, maybe it is time to start looking, and maybe create more consistency when we are talking about the fundamental failure or survival of the structures.

Mr. GINGREY. Right.

Ms. CHAPMAN-HENDERSON. And I don't think we have drilled into it that much yet.

Mr. GINGREY. Thank you. And I think I will go directly to Dr. Hays now, and then, let Dr. Levitan give a follow-up comment.

Dr. HAYS. Thank you. The issue of coordination is one that I have thought a lot about, with respect to this working group, because frankly, this working group has faced some challenges, I think, in generating the same level of interest and engagement that we see with some of the other interagency working groups that OSTP helps coordinate.

And I think an obvious comparison to make is between the Wind Interagency Working Group and the Subcommittee on Disaster Reduction, which I mentioned in my opening statement, and is the all hazards approach to interagency coordination. One of the things that strikes me as a key difference between those two groups is the all hazards approach, and so, the Subcommittee on Disaster Reduction, in taking that approach, I think that provides tremendous impetus for agencies to come to the table, to make sure that the different types of hazards-related research are represented there, and so forth.

The very narrow, really slice of the overall R&D picture that is represented by windstorm-related research presents a challenge there, I think. It has been mentioned by one of the other witnesses that the agencies in, with respect to windstorm research, have very defined activities, and I think that is appropriate. They are complementary, and each agency undertakes those activities very much in keeping with their other types of activities.

So, the National Science Foundation has a very different approach to funding windstorm-related research than, say, FEMA. So, Mr. Chairman, I think that that is something, and Mr. Gingrey, I hope that this committee will consider whether or not it makes sense to treat individual types of hazards in this way that we have been, versus the all hazards approach, which I think is supported not only by our success with the Subcommittee on Disaster Reduction, but on things like the RAND Report, and other approaches.

Mr. GINGREY. Dr. Levitan.

Dr. LEVITAN. Excuse me. I think that the individual agencies have done what they can within their resources, and are making significant progress, but the program is, really provides them the opportunity, and hopefully, in the future, to do a better job and enhance their coordination, and I think that is why we really need to move forward with this, and expand, and the interagency working group, and to provide for better coordination.

Mr. GINGREY. Mr. Chairman, as my time in this first round is winding down, I want to ask unanimous consent, if any of the Members want to submit questions for the record for Dr. Reinhold, if that would be allowed.

Chairman WU. Without objection, so ordered.

Mr. GINGREY. Thank you.

Chairman WU. Dr. Ehlers for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman. Unfortunately, I have three hearings going on simultaneously, so I missed the testimony and early questioning. If I ask a question that has already been asked, just let me know, and I will withdraw it.

But just following up on a comment I made at a hearing a week or two ago, it is a real puzzle to me, as someone who lives in the frozen North, and has also lived in earthquake-prone California. We have adopted building codes in those areas which work extremely well. I have never heard of any time recently that a house has collapsed because of heavy snow on the roof in our area, and the earthquake damage has really been minimized in earthquakes by the strong building codes out West.

It has always puzzled me why we haven't taken the same care and rigor in the hurricane-prone areas while we know that we can mitigate a lot of the damage, and prevent a lot of the damage, by appropriate building codes, and it just doesn't seem to happen. And I am curious, if you can give me any insight as to why this slow rate of adoption of improved building codes, in areas that are prone to windstorms.

Anyone have any wisdom to offer on that issue?

Ms. CHAPMAN-HENDERSON. I will certainly try. I think there are those in the construction profession that are fearful of the costs, and some of those fears are accurate. I mean, the costs of constructing a home is an essential component of whether or not people can have a home. So, I think this is where information and knowledge transfer comes in. If we can complete the research and identify, perfect those affordable techniques, and then communicate, you know, we are talking about incremental increases in costs that make a difference between surviving a windstorm or not, I think we go a long way.

There is, perhaps, a fear of the unknown tied up in the conclusion ahead of time that it is going to make homes too expensive for our part. We have always felt that the home that was built in a way that allowed it to fail was the ultimate expensive home, so it just didn't make any sense to us, and I think that is pretty much the core of what we do.

But there is some opposition in the field. There has been talk, also of, again, looking back at highway safety, of finding a way to reward those states and municipalities that do embrace, intact, the national model codes, and possibly providing a carrot of sorts, so that there is enhanced mitigation money, pre-disaster, or other initiatives, that could help motivate the communities to recognize that they have to do their part, too.

Mr. EHLERS. Yeah, but you know, I have served in local government, too, and every change you make, there are people complaining about the expense, sometimes legitimately, but we still increased the building code, or changed the building code to accommodate that. And California has probably had the greatest expense. The occurrence of earthquakes is very unlikely, and yet, we have very good building codes which minimize the damage, and if you add up the cost of all those changes in the building code, it is hard to justify on the basis of any individual residents, but in terms of the overall picture, and lives saved, it is a good investment.

Why have the protesters against wind damage building codes been so, either so strident or so successful, whereas it has not been an issue in other areas? Every time you change the building code, you get screams of anguish, but you still do it, because if it is the right thing to do.

Ms. CHAPMAN-HENDERSON. Well, two points. One is, I couldn't agree with you more. It is the right thing to do, and that is, again, the core of what we do. I think one of the challenges is it can be very technical.

I will give you an example. There is a provision that is often used at the local level, when the residential code is adopted, relating to windstorm. And by its insertion, it makes a requirement for having shutters or opening protection unnecessary. And the insertion allows people to have an option. Instead of shuttering a home at the time of construction, you can do something called design it to be partially enclosed, or design it for internal pressurization, which sounds really good. And it does, in fact, make the structure stronger.

But the interesting thing to us is that the designing for internal pressurization option, my understanding is was originally put in place for barns, because barns don't really need shutters. If a storm is coming, the concept is you probably get your horses or other animals out of the way, so it caused an undue expense to the farmer. But putting something in place that allows homes to be designed and built that way, essentially leaves those homeowners without the ability to shelter in place, because they won't have opening protection, and it is critical, as roof performances in high wind, covering your windows is a pretty well established factor, as well. But it is so technical, and it is hard to understand, and it is engineering, I think sometimes, we don't understand what is being done.

Mr. EHLERS. Well, I have to admit, I am dismayed and also amused every time there is a hurricane pending, TV shows, all the people running down to Home Depot or Lowe's or whatever, buying particle board, hammering it over their windows, which of course, creates damage to the woodwork and so forth. And it is really quite an expensive option. I can't believe that doing that on a regular basis is any cheaper than building it right in the first place—or is, I am sorry, is any more expensive than building it right in the first place.

Ms. CHAPMAN-HENDERSON. I couldn't agree more, when you add the social costs, as well.

Mr. EHLERS. Any other comments, Dr. Levitan?

Dr. LEVITAN. Yes, I will address more, maybe more the technical side of your question. I think the adoption of the codes that has been addressed. One, actually, there have been, particularly in

New England in the last several years, there was some significant roof collapses from snow load, but the nature of snow load is a gravity load, acting down. The structures typically are designed fairly well for that, and where earthquake and wind loads have lateral loads and uplift loads, which is more unusual, and takes more care to be able to design for.

The better performance of structures in earthquakes, I think has, in large part, has been due to the success of the NEHRP, the National Earthquake Hazard Reduction Program, which has, for many years, gone out after the earthquakes, and found out exactly what worked and what didn't, and then had the significant funding to make major advances in the codes. There has been dramatic changes in our design practices and technologies and techniques and products that we use for earthquakes. And to get that into the code, and to move that forward, whereas, we have not had that same opportunity in wind hazard mitigation.

And certainly, even the codes that we have now, they do a good job of reducing, when they are adopted and enforced, but we still have a long ways to go, in terms of moving our codes, our building codes for wind to the next generation.

Mr. EHLERS. Well, are you suggesting that we need more research?

Dr. LEVITAN. Yes, very clearly. The research and the technology transfer, to take the research findings. And we have sort of a backlog that we have built up of research findings, and within the research community, and even internationally, we have a lot of research which has not been able to have been translated into codes and standards, because the funding for that is very difficult to get. That is generally too applied for the National Science Foundation, and there isn't other, there typically isn't industry funding or other funding opportunities available to do that tech transfer.

And so, the national program here would be the place to be able to provide that, and get a lot of bang for the buck right now.

Mr. EHLERS. Well, Mr. Chairman, I suggest you take care of that problem. Thank you.

Chairman WU. The gentleman's comments are always trenchant and on point, as are his questions. And next, the gentleman from Nebraska, Mr. Smith, recognized for five minutes.

Mr. SMITH. Thank you, Mr. Chairman and witnesses.

Coming from hail-prone, tornado-prone areas, situations in rural Nebraska, it has been interesting, as disasters have stricken the country in various places. My constituents watching tax dollars go to certain areas of the country is one thing, but when availability of homeowner's insurance becomes scarce, is quite another. And so, the attention it has had around the country, and this is an interesting discussion here.

And you know, the mitigating efforts on the part of auto dealers, for example, building canopies so they can buy more affordable hail insurance, it has been interesting. It has been expensive up front, obviously, when an automobile dealership builds canopies for their entire inventory, but it is a cost savings in the long run, and certainly, it is a good business decision.

But as we are discussing, perhaps Ms. Chapman-Henderson, on the training, how many people have been trained through the Blueprint for Safety curriculum?

Ms. CHAPMAN-HENDERSON. Last year, approximately 2,500. We are currently focusing, our work is very state-specific, because the training is usually part of an overall initiative embrace by a state, so we are right now training inspectors in South Carolina. I don't know the specific number of how many. When Florida put their mitigation program in place, there was a huge training piece to that, and we provided it.

Mr. SMITH. What would you say are the skills that would be taught through a course?

Ms. CHAPMAN-HENDERSON. Well, first, the first chapter is on just fundamentals of wind design, and understanding some of the basics, just on roof shape, and this whole concept of pressurization of the structure. You know, one of the things we used to believe, and I think a lot of consumers still believe, is that we should crack windows open when tornadoes are coming, and we have learned through the work of Dr. Levitan and others that wind effects on structures are such that we don't want any wind in the house.

So, we start with those fundamentals, and we teach prescriptive methods for roof attachment with enhanced nailing, secondary water barrier, identifying code plus or impact resistant or wind resistant shingles.

Mr. SMITH. Have you seen the students for, say, of the training, able to enhance their employment position through the course work?

Ms. CHAPMAN-HENDERSON. Yes, in fact, it is ironic, because we used to worry about being able to get contractors to participate in our program, because there was so much work going on with the housing boom, but there has been an unintended but positive consequence of this specialty that has been created across the country called wind mitigation. Much like the medical profession, if you are an orthopedic surgeon, you don't necessarily practice cardiology. So, a lot of contractors, even some appraisers and others, have been able to cross-train into performing wind mitigation retrofits.

As you know, the new construction, the building code is essential for all the new construction, and of course, post-disaster, to bring that housing stock into current times. But our great challenge is the existing stock, and retrofitting it. So, it is becoming a specialty area in the trade. And in the profession, it is not vast yet, but it is growing, and it is becoming something that I think we will see over time will take hold, because there are so many things you can do. If you can get in your attic, for example, you can put additional metal connectors to enhance the connection between the roof and the wall, and that can make all the difference in a high wind event.

You know, there is also the notion of existing activities for people like roofers. If roofers are trained and cross-trained into wind mitigation, they recognize that the ideal time to enhance the strength of a roof deck is when you have taken the covering off, and that is where that handful of additional nails, maybe of a specific type, maybe, you know, ring shank nails, that can make the difference in keeping that deck on.

There is a pretty famous story that we always talk about, about Hurricane Andrew, where the Miami Herald had a headline. It looked like a football score, and it said Habitat 24, Andrew 0. And what it was talking about is that 24 homes built by Habitat volunteers survived Hurricane Andrew nearly intact. In fact, we raced to the scene, only to find out they were fine. The unfortunate part is that surrounding those homes, there were commercially developed homes that were decimated. So, the engineers came in, they looked at, you know, the damage investigation revealed that volunteers nailing a roof deck on typically say to themselves, you know, I guess if one nail is good, two is even better, and unwittingly, enhanced the nailing pattern, and thereby, the strength of the deck. So, those houses were just fine, and it is those types of things that I think, you know, we need more research so we know specifically what is working, and learning things like that, just a handful of nails, what an essential element, and when you think about the economics, pretty powerful.

But we aren't yet in a place where everybody knows that, and that homeowners know that, and roofers all know that. And I think we have an opportunity to change things by making that happen.

Mr. SMITH. Well, I better, Ms. Chapman-Henderson or Dr. Levitan, are we seeing positive patterns of consumer behavior post-storm event? Are we learning from our mistakes?

Dr. LEVITAN. Well, I guess I can speak to maybe recent activity in Louisiana.

It is very slow. It is, especially after such a large scale event, like a Katrina or Rita, as important as it would seem, there is so many other activities, like where am I going to stay, and my house and my job, and all of those things, that it is kind of hard for it to get traction. I think it seems that, for example, the state did a good job, and within a few months after Katrina, we passed statewide mandatory building codes, and that is being phased in, and of course, training and education of even the building inspectors and the design profession is a challenge that is going to take many years.

And we are, I think the education of the consumer, and getting to the point where the consumer is starting to ask for the, it is really just in its infancy, and so, we are three years out from Katrina now, and it is, I would say it is very slow. At least it is on the right trajectory. People are starting to look at it. You occasionally see, and I know in Florida, it is much more common. You occasionally see a commercial on the television for hurricane shutters now. We would have never seen that before. And there are a few developments that are starting, and people are starting to ask about you know, what is this, a fortified home program. My colleague, Dr. Reinhold, couldn't be here today, but the IBHS has their program, and they are making some inroads in Louisiana, and I have heard that some builders are starting to use that one.

So, it is a slow process, but it is, we are making some progress, I think. Thank you.

Mr. SMITH. Thank you, Mr. Chairman.

Chairman WU. Thank you. It is the Chair's intention to give the gentlelady from California a moment to get settled, and so the Chair will recognize himself first for five minutes.

Dr. Levitan, you cited the importance of future research, but that there is a lot of existing technology or research that has already been performed, where there has not been adequate transfer of that knowledge to application, and Ms. Chapman-Henderson, you cited some specific examples, perhaps, of you know, very straightforward steps that could be taken, that are also, in essence, tech transfer types of issues.

Dr. Levitan, can you tell us about some of the other already done research, the existing technologies, which have not been adequately transferred, and your ideas about how that transfer might occur better?

Dr. LEVITAN. Yes, Mr. Chairman. As an example, I am a member of the ASCE–7 Wind Load Subcommittee. That is the committee that writes the National Wind Loading Standard, which gets adopted into the model building codes. And we are going through a cycle right now. The document is revised every few years, and we are examining the methods that we use to determine what the provisions that go in the codes for how do you figure what the wind loads are on a building.

And the discussion at the last meeting was, are the two methods that we have in the building code right, or in the ASCE standard right now are based on 30- or 40-year-old data. And in those days, when you did wind tunnel, that was from, it came from wind tunnel tests, and there might be four or five or ten pressure taps on a building, where you measure the pressures at just a very few number of locations on the building. The technology, the wind tunnel testing technology today is so far advanced, where you routinely would measure pressure simultaneously over a 1,000 points all over the whole building, so you really understand that the wind loading is happening on the whole building all at once, and yet the methods that we use in the code are based on much, much older technology.

So, we have a lot of data that is available out there, and NIST is working on a program right now for what they call a database-assisted design, where they are slowly taking some of that wind tunnel data, and trying to develop a method where we can make some use of that, but there are real opportunities there, where there is so much tremendous amount of data, the wind tunnel technology has advanced so far, but most of the benefits of that have not found their way into the building code yet, and that would need some additional testing with the technology that we already have to do what we call parametric studies, the building code only has rectangular boxes. The only kind of building, if you look in the code, and see how do I figure the wind load on a building, it will have a picture of a rectangular box of a building with maybe two or three different roof shapes, a pitched roof, or a gable roof, or a hip roof.

But what if you have buildings in plan, that are L-shaped, or T-shaped, or have balconies, or have all these other things? There is nothing in the code for that, and we have the technology to be able to do that with our advanced wind tunnel testing. It hasn't been done.

Chairman WU. Dr. Levitan, I am sure you have many other examples, but let me jump to Dr. Hays for a second, and Dr. Hays, there appears to be a tech transfer problem of existing knowledge to designers, builders, drafters of building codes. What, in your view, can the Federal Government do to promote this technology transfer? Which federal agencies do you see as playing a role in that?

Dr. HAYS. I think there are a couple of different answers. First of all, Dr. Ehlers, I think, hit on the fundamental issue here, which is, and other witnesses have elaborated on it, which is that we have a lot of this data. It is not necessarily getting translated to those who write local building codes, zoning laws, et cetera.

I think that is where the primary breakdown in communication is, and I would argue that, and Dr. Ehlers made this point, I think, very nicely, that there does seem to be somewhat of a difference when you look at windstorms, versus other kinds of hazards, such as earthquakes. I don't know why those differences exist, but it sounds to me like an area of social science research that is ripe for exploration, and I know NSF funds exactly those kinds of research questions.

In terms of what federal agencies are involved in the technology transfer right now, clearly, NIST has a central role. And as I mentioned before, because many NIST scientists both do their government-related research, and then also sit on the standards development committees, like the ones that ASCE and others run, they have a direct flow of information, from what they know from their government research, going directly into those standards-building, standards-generating committees. That is clearly a very important mechanism. Again——

Chairman WU. Dr. Hays.

Dr. HAYS. Yes.

Chairman WU. I am going to interrupt you, because my time is expiring. You mentioned NIST, and Dr. Levitan, I believe, in your testimony, you recommended that NIST take a leading role in this program. And I want to give you a chance to expand on that, and explain why you think NIST is an appropriate agency.

Dr. LEVITAN. Yes, thank you, Mr. Chairman. I think, because they have the expertise and experience, directly in wind hazards. They have folks working in the wind hazard mitigation area. This program has significant parallels to the National Earthquake Hazard Reduction Program, which they are the lead agency for now. And so, it seems to be the right fit of an agency that does research and does tech transfer, as opposed to say National Science Foundation, which would only focus on the research aspects. And so, from the agencies involved, NIST really seems to be the best fit.

Chairman WU. Thank you, Dr. Levitan, and at this point, I would like to turn to Dr. Gingrey, five minutes.

Mr. GINGREY. Mr. Chairman, thank you.

I want to address this question to Ms. Chapman-Henderson. You know, we, the Federal Government we, a lot of times, put unfunded mandates on a lot of industry, I am thinking particularly in the electric generation industry, particularly coal-fired power plants, and some of these very old, existing for 20, 30, 40 years, and all of a sudden, a decision is made by the Federal Government because of the Clean Air Act, that you have got to retrofit to an extent that you would almost have to tear the place down, or convert over to natural gas, which is much more expensive, and of course, used in a lot of other industries, and we have a limited supply.

I am thinking, of course, in cities like my city of Atlanta, the metropolitan statistical area, which is non-attainment, and people have to have their vehicles inspected every year, every year, and a lot of times, you know, you got senior citizens driving an eight year old car that can't really meet the standards, and it is an unusual burden on them.

So, my question is that the, leading into the question you, I know you are involved in a lot of state-of-the-art retrofit technologies for older construction, in regard to natural disaster mitigation, in particular wind, and certainly, I think that is great, what your organization is doing in educating the public, but it is important to know, I think, for the Committee, to understand the cost involved in retrofitting, and are you more focused on new construction, and as these houses are replaced, old housing stock, of course, and modernization of same, but I don't think it would be very cost-effective to require people to, you know to, by ordinance of the local government, building codes all of a sudden have to go back in and change something that wasn't the law when they moved into their abode.

Ms. CHAPMAN-HENDERSON. And the ideal times to change or retrofit existing property are when you are rebuilding from an ordinary incident, possibly a house fire, or post-disaster, after a windstorm event, you really have an opportunity to get in there and do some things differently.

As far as, and let me just say this, our major focus is helping consumers make informed choices at the market level. What the developers and the builders that we work with every day tell us is, if it is a level playing field, and it is either in the building code or everybody wants it, and the customer wants it, it will happen. And what we have seen in places where the model codes have been enacted is that the costs of doing the wind mitigation techniques at the point of new construction go down, because the marketplace for shutter options or impact windows, or all the different things, it is, the scale introduces a lot of savings, and over time, it becomes less expensive, say, to buy shutters in Miami, where they are required, than it is possibly up on the coast of, you know Saint Simons. So, there is, because there is more options in the marketplace, and what the builders always tell us is, if everybody has to do it, it is not going to adversely impact me, and that is where, you know, having it in the code, over time, is helpful.

But on retrofitting, I think one example to look at, because of the number of homes that have been done, there are approximately 20,000 homes that have been completed due to the My Safe Florida Home Program, and their average expenditure, by the homeowner, and it is matched by a matching grant, is around $3,100. So, if the homeowner goes in, and says I want to shutter, replace my garage door with an impact resistant door, and if I can, through attic access, install some retrofit hurricane straps, to keep the roof and the wall connected, that is around $3,100 expenditure on their part, and it is matched by another $3,100. So, it is about $6,200 if they want to make the investment.

Now, to the point on insurance, in those same markets, they have some of the highest insurance rates in the country. So, on the wind portion of the insurance, in those markets, especially in Southeast Florida, they can save up to 52 percent on the wind premium, so there are substantial every year savings on the insurance that follow the investment in mitigation, and in pretty short time, it pays for itself.

When we look at all of it, though, what we find is the financial incentives are essential as a support, but I think what really helps people, you know, decide to either buy or retrofit or build differently, is when they think about the safety aspect. Just kind of putting themselves in the place of the people who went through Katrina, or any of the, you know, tornado outcomes, you know, they envision what they could do differently ahead of time. That is the most powerful motivator of all.

You know, one of the, you know, especially relevant to the experience that both of you have had in your districts, you know, with tornadoes, the thing that is sad, I think, in this country, is that most homeowners and many builders don't even know that there is a tornado safe room that you can affordably construct, either retrofit or new construction, in homes. And that is a life safety bunker. That is not really about the house. That is about the survival of the family, and the cost of constructing those has come way down over time, as well. That is what we would like to do. As long as people know ahead of time, and can make that decision, to us, that is the key.

Chairman WU. The gentleman's time has expired, and next, the gentlelady from California, Ms. Richardson.

Ms. RICHARDSON. Thank you, Mr. Chairman, and first of all, let me applaud your leadership in having this hearing today. Given what has just happened in the last couple days, it is quite timely.

My first question is for Dr. Levitan. Could you please discuss with us how the lack of federal funding for wind engineering research effects—excuse me, I am sorry—could you discuss for us the lack of federal funding for wind engineering research, and how it affects the pipeline of students interested in pursuing wind engineering or disaster-related engineering as a career?

And a follow-up to that is, what impact do you see of the lack of students participating, will that have on our future, in terms of building safety?

Dr. LEVITAN. Thank you. That is an excellent question. That is a key part of the problem is——

Ms. CHAPMAN-HENDERSON. Well, we have great staff.

Dr. LEVITAN. Yeah. We, the professor in me comes out sometimes. There are really comparatively few faculty that work in the area of wind hazard research, and that is 100 percent correlated to funding. Faculty have to get promoted and tenured, and how do they do that? They get funded to do—they have research fundings. They have to support their students, et cetera, and so, at the beginning of the chain is, sort of, if there is no university research being done, then there are very few faculty that work, and have any expertise in the area, and certainly, experimental work is expensive. And it is difficult to do a lot of kinds of things without experimental facilities.

And so, that leads into a chain of very few graduate students and undergraduates working in the laboratories, et cetera, moving along. And so, that filters out that you have few people with any expertise that can get out of school. Actually, we have, the problem is there is not much in the way of curricular materials for—compared to earthquake, which has had the funding in recent years. There are textbooks, there are books out there, in California, most of the schools, undergraduate programs, you have specific courses in earthquake engineering, or they incorporate a major component of that into their, sort of their senior design courses. And we don't do that for winds and hurricanes. There is very little information out there, because the chain never really gets started, because that is where it starts is at the top, as you pointed out, with the university research.

And then, it gets filtered down into practice. And when you don't have that, and you don't have the core of faculty and graduate students working on that it, you just don't have the trained workforce, then.

Ms. RICHARDSON. Might I suggest that maybe you put together some recommendations for this committee, as well as the Administration, of what we should be thinking about in the upcoming years, of how we can ensure that we are developing a pool of folks, so whatever it might be, and whatever level that you recommend, that we begin to address, and that that way, we can appropriately ensure that we do have people who can make these Twenty First Century recommendations to improve our safety.

Dr. LEVITAN. Yes, I would be very glad to. There are a few programs out there. At my alma mater, my colleagues from Texas Tech have a wind science and engineering Ph.D. program, and they were funded by the National Science Foundation through their IGERT, their Integrative Graduate Education Research and Training Program, to build that—a very unique and innovative. We received a grant from the National Science Foundation to build some curriculum materials for hurricane engineering. The first, really, the first program of its kind in the country.

And so, there are some fledgling programs, but for those to be expanded, I would be glad to provide those recommendations. Thank you.

Ms. RICHARDSON. Thank you. And then, my next question is for Dr. Hays. This weekend, I had the opportunity to travel on a Congressional delegation to New Orleans and Mississippi and Baton Rouge, and we saw some of the results still, now three years, it is going to be the anniversary of those very devastating hurricanes, of both Katrina and Rita.

Can you tell me, in your mind, do you feel that, based upon the work that your organization has done, have insurance companies appropriately taken into effect what your recommendations are, and do you find that the policies are now reflective to, in fact, protect our consumers?

Dr. HAYS. I am not sure that I am the best person to speak to insurance policies. That really takes us outside of the S&T domain that I am most familiar with, and that our office is most——

Ms. RICHARDSON. So, let me clarify my question, and I have got about 30 seconds, so I am going to be as brief as I can. It is my understanding that folks were sent the FEMA, NIST, and NSF, down to you know, assist and coordinate with the efforts. Some of the problems that have been said about Hurricane Katrina and Rita, was that the policies that people had were not consistent with understanding potentially what damage could have occurred. And so, my question is, from what you have learned, and what these various organizations have observed, have those indicators been passed on to the appropriate folks, who can then assist our consumers to ensure that they, in fact, have the right protections?

Dr. HAYS. Okay. So, I think the answer is that that is happening. It is a process that is still ongoing. There is a saying in this field that we are always prepared for the last storm. And that is, in part, because we learn so much from each event, as it happens. So, as you mentioned, all these different teams, combined government and private sector researchers down there, are learning from Hurricane Katrina. A number of different agencies have participated in that. Some of those results are starting to come online, so to speak, but I think that is very much an evolving process. And so, we need to look to the future to see the sort of uptake of what we learned from that event.

Ms. RICHARDSON. Thank you very much, and you were very kind, Mr. Chairman, to allow me that additional 30 seconds.

Chairman WU. I thank the gentlelady, and the gentleman from Michigan is recognized for five minutes.

Mr. EHLERS. Thank you, Mr. Chairman. I—first of all, I was amused by your comment about the Habitat for Humanity homes. I was not at all surprised when I saw that scorecard years ago, because I have worked on Habitat for Humanity homes, and I am from the old school, if one nail is good, two is better, but I remember particularly working on one house where I was joining the roof to the wall, and I am sure if that roof is ever blown off, the wall will go with it. Now, maybe that is not an efficient way to do things, but it certainly saves a lot of trouble later.

Dr. Hays, you said in your testimony that "the benefits of this improved understanding will not be fully realized, however, until it is incorporated more completely into actions at the State and local level, both through building codes, design standards, and construction practices." With which I fully agree. But what plans does the interagency working group have to do that, and I have a follow-up question relating to NIST and NSF, if you would answer the first one.

Dr. HAYS. So, the issue of uptake at the local level is one that goes beyond just the science and technology. I mean, certainly there are market mechanisms that can be brought to bear to encourage uptake, incentive programs and so forth, that I think sort of go well outside the S&T arena that we are mostly talking about here.

In terms of what the agencies can do, though, I think there is sort of a two step process. Once the research is done, we understand what the science and engineering results are telling us. That first step, and I know you are very familiar with this, is the translation of that into standards and so forth, and so, these consensus-based standards organizations that NIST is very much engaged in, for example, are a place where the Federal Government, I think, does a good job of helping to transfer knowledge.

Where I think there remains to be a lot of work to be done is that second step, which is the transfer of those standards that are developed by the engineers, by the scientists, at the local level. And that is something that I think the federal agencies in this program tend not to be as engaged in, because their emphasis is on the science and technology. But certainly one that I would be interested in learning more about, as you have highlighted a very important problem in the overall process.

Mr. EHLERS. Another aspect of this. I was struck, in listening to the comments back and forth, that this is a building practices type of thing, and I would not expect NSF to be active in it, and I was surprised by the number of times people related work done by the National Science Foundation. I don't think any of my colleagues are aware of that, and the importance of that work. Similarly, the comments about NIST, a number of things over.

And we fail, in the Congress, to adequately fund these research organizations. Many Members, I think, believe it is pie in the sky pure science, but it has direct applications. And I would hope that you would continue to work with those of us in the Congress, particularly this committee. I know Mr. Wu and Dr. Gingrey feel very strongly about this, just as I do, that we are not adequately funding our research institutions. I would hope that your agency would join with us in that effort, to persuade the rest of our colleagues to do it right.

And since the President will be leaving office shortly, you can throw discretion to the winds, and request mammoth amounts of money for these agencies in next year's budget, even though it may not last, but it still would be a good show for the next Administration to deal with.

Dr. HAYS. Well, Mr. Ehlers, you have mentioned two agencies that, of course, are within the American Competitiveness Initiative, so——

Mr. EHLERS. Right.

Dr. HAYS. I feel very comfortable in saying that we agree with you that those are two agencies that do need additional funding, and we are hoping that the appropriations process will yield that this time.

Mr. EHLERS. Right, and I thank you for all your work that you and Dr. Marburger did on the COMPETES Act, and especially, that the President endorses so strongly.

Thank you. I yield back.

Chairman WU. I thank the gentleman. And I just want to make a comment before closing.

And it is, in part, Dr. Hays, a response to what I am reading between the lines in some of the testimony that you gave, and also, the answers that you gave to some of the questions, and some of the colloquy with Dr. Ehlers. And that is that you seem to be advocating for an all hazards approach, rather than this wind hazard program, which has not received, it seems to me, either adequate attention or adequate funding.

And I want to point out that it has been cited several times, both by the witnesses, and by Dr. Ehlers, that the National Earthquake Hazards Reduction Program at NIST is a success by many metrics, that earthquake codes have responded, or have been changed all around the country. And I will take into consideration what you have had to say about taking an all hazards approach, but I do want to point out that this authorizing legislation passed in 2004, was bipartisan in its original sponsorship, was passed in a bipartisan manner through both chambers of this Congress, and was signed by President Bush, and it is the law of the land. And if this Congress passes the legislation again, I believe that what the witnesses have brought to light today, and the concerns of the Members of this subcommittee, are that whatever reauthorizing legislation we pass be implemented with heart and with resources, and with thoughtfulness.

I know that we all work hard to serve this nation well, and as we move forward in any reauthorization, we do want the future to be an improvement on what has happened between 2004 and now, with respect to this program.

I want to thank all of our witnesses for coming the distance and testifying today. I appreciate that very, very much, and I understand that you know, one of our witnesses was unavoidably detained, as I have been numerous times in Chicago. And it is the Bermuda Triangle of commercial flight, but I am sure that that is a problem that we will work on and solve, eventually, also.

The record will remain open for additional statements from Members, and for answers to any follow-up questions the Committee may ask of the witnesses. And with that, I again thank all of the witnesses. I thank the Members for their participation, and the witnesses are excused, and the hearing is now adjourned.

[Whereupon, at 11:31 a.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Timothy A. Reinhold, Senior Vice President of Research and Chief Engineer, Institute for Business and Home Safety, Tampa, Florida

Questions submitted by Representative Phil Gingrey

Q1. In your testimonies, you and Dr. Levitan propose that Congress assign NIST as the lead agency for NWIRP. How would designation of a lead agency improve the performance of the program? What activities could NIST take as a lead agency that cannot currently be done under the National Science and Technology Council coordination?

A1. Designation of a lead agency provides a permanent home for the program with staffing, a web site, regular communication and a focused committed group who own the program. That sort of leadership is easily lost with a coordination council. NIST is, in our opinion, the correct agency to task with leadership of this program because the heart of the program, if it is to be successful, is pre-event mitigation including: retrofitting existing buildings and structures or improving the hazard resistance of new buildings and structures through stronger building codes and standards, adequate enforcement, training and education; improved methods for evaluating the hazard resistance of materials, components and systems; and finally improved methods for assessing the costs and benefits of all these activities.

While the activities and funding proposed for FEMA, NSF and NOAA, among others, all contribute to the bigger picture of adequately understanding the problems and issues associated with windstorm damage and will help lead to successful solutions that reduce damage, injury and losses, the physical changes to our infrastructure are key to beginning to see actual reductions in losses. NIST is the appropriate agency to conduct and fund the kind of applied research needed and to lead the necessary technology transfer. NSF does not typically fund applied research and will not fund testing programs designed to develop databases needed to improve building code provisions. FEMA typically has very little pre-event discretionary funding and it does not have a strong research mission. NOAA is generally concerned about predicting and characterizing weather events; the kind of fluid structure interaction that characterizes windstorm effects on buildings is outside its mission.

Despite inadequate funding, NIST has done a good job with management of the National Earthquake Hazard Reduction Program since it was assigned this responsibility. There would be some synergies and critical mass benefits to having both programs managed by the same agency. We still see a role for the National Science and Technology Council in coordinating and monitoring the activities of the various agencies. However, we believe that having a single agency leading the effort to more clearly focus the contributions of the various agency activities on the mitigation mission would be quite beneficial.

Q2. What are the linkages between wildfire damage and wind research and development? Can information gleaned from studying severe weather also improve our ability to forecast wildfire movements?

A2. Not surprisingly, wind significantly changes the dynamics of wildfire spread and creates conditions where firefighters have little control over the spread. Research being conducted by NIST and others suggests that the wind-structure interaction, which has long been recognized as important to wind loads, is also critically important to the assessment of ignition risks and predicting wildfire spread. Close to the Earth's surface, the wind characteristics tend to be dominated by the interaction of the wind with topography, vegetation, buildings and structures. While there may be some differences in flow characteristics because of the thermal effects of the wildfire, as wind speeds increase, these differences are likely to be reduced. Thus, we believe that analytical tools to understand the effects of turbulence on wind-structure interaction will be useful for improving our ability to predict vulnerabilities from multiple hazards that have a wind component.

Q3. Do any members of the IBHS provide a discount to homeowners, builders, or businesses that adopt and use the latest building codes? With what professional organizations do you coordinate during the development of your building codes? What impact do your suggested codes have on the construction industry?

A3. All insurance companies writing wind-related property coverage in Florida provide some sort of discount for structures built using the most up-to-date building codes. The amount of the discounts and the ways they are administered is left to the discretion of the individual insurers. IBHS does not get involved in any under-writing discussions. We also have a number of State wind pools, as well as some private insurers that have begun offering discounts for homes built using IBHS' *Fortified . . . for safer living*™ criteria, which is actually "code plus."

We work with the International Code Council and the National Fire Protection Agency on the development of their national consensus model building codes where all stakeholders participate in the code development process. IBHS does not have or maintain its own building code. We do have a voluntary "code plus" designation where we have worked to establish a series of requirements that our analysis indicates will produce a superior building that will likely perform substantially better than surrounding buildings when a major event occurs. A key element of that designation program is a design review and a series of inspections, which assures that the key hazard resistant elements are actually built into the building as designed and as required for the designation.

Frequently, stronger building codes and our "code plus" designation add to the first costs of the building. However, we believe that those higher initial costs need to be assessed in terms of the overall life cycle costs of ownership of the building and the peace of mind and reduced chances of disruption to lives and the community that are associated with the improved hazard resistance. Risk modeling companies and various benefit-cost analyses for proposed strengthening of building code provisions have generally shown significant positive benefit-cost ratios for seismic and windstorm upgrades.

The amounts of the benefits certainly vary depending on the building size, probabilities of occurrence of events of certain magnitudes and type of construction. We believe that improving our ability to carry out robust benefit-cost studies should be a key goal of the National Windstorm Impact Reduction Program. Clear demonstrations and justification of the benefits will go a long way toward convincing a wide variety of public and private entities that they should be valuing hazard resistant construction and providing incentives to encourage construction of these types of buildings.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Marc L. Levitan, Director, Louisiana State University Hurricane Center; Charles P. Siess, Jr. Associate Professor, Department of Civil and Environmental Engineering, Louisiana State University

Questions submitted by Representative Phil Gingrey

Q1. In your testimonies, you and Dr. Reinhold propose that Congress assign NIST as the lead agency for NWIRP. How would designation of a lead agency improve the performance of the program? What activities could NIST take as lead agency that cannot currently be done under the National Science and Technology Council coordination?

A1. The National Institute of Standards and Technology (NIST) is the best choice as a lead agency for NWIRP to improve performance of the program. NIST's Building and Fire Research Laboratory has a long history of research and technology transfer in the study of wind hazards and wind hazard mitigation (the statements of Drs. Hays and Reinhold for this hearing provide details on some of NIST's recent activities in support of the wind engineering).

Of the federal agencies involved in the NWIRP, NIST has the most standing within the engineering research and technology transfer community in the area of wind hazard mitigation, making their leadership more effective than that of other agencies. NIST has the most interaction with industry and building codes and standards activities, which are critical components to effective wind hazard mitigation.

The NWIRP is very similar in nature to the successful National Earthquake Hazards Reduction Program (NEHRP) for which NIST already serves as the lead agency. NEHRP program activities span the range of basic research, applied research, and technology transfer and education, working with other government agencies, universities, industry, and nonprofit research and technology transfer organizations. The NWIRP program has a similar range of activities and partner agencies and organizations, so NIST can leverage its success leading the NEHRP into ramping up activities of the NWIRP.

Since NIST has expertise and experience with basic research and applied research and technology transfer in the area of building technologies, both in-house and through management of externally funded projects, they are in a position do a better job coordinating the overall NWIRP efforts than the current arrangements.

Question submitted by Representative Laura Richardson

Q1. Can you please provide recommendations on how the pipeline of engineers and other professionals with wind hazard mitigation expertise can best be developed?

A1. Very simply, developing a pipeline of engineers and other design professionals with wind hazard mitigation expertise is primarily dependent on availability of funding for wind hazard mitigation research.

Students graduating with Bachelors or advanced degrees in civil engineering, architecture, and construction management today have little or no formal education in wind hazards and mitigation. Much of the reason behind this phenomenon stems from the current paucity of funding for wind-related research. The expertise to teach the kind of classes and to develop the textbooks and curricular materials needed generally resides in university faculty. There are only a small handful of faculty at U.S. universities that currently work in the area of wind hazard mitigation, which is directly correlated to research funding levels. If university faculty members cannot obtain funding in a certain area, they will not get promoted and tenured, so they choose other areas for their research careers. With little research support available, there are very few graduate students working in this area, so we are not effectively training a new generation of faculty and research leaders.

Comparing this situation with earthquake hazard mitigation is very instructive. The NEHRP has provided a significant level of research funding for years now, having a hugely effective impact on seismic hazard reduction. There are very active programs in earthquake research, education, training, and engineering practice, particularly in high seismic areas. There are many faculty active in earthquake engineering research and education, therefore reference books, textbooks, and training materials for continuing professional education are widely available. Most civil engineering curricula on the west coast have required components and sometimes entire courses in seismic design at both the undergraduate and graduate levels. One of the end results of the NEHRP has been creation of a current generation of design professionals equipped with the fundamentals earthquake hazard reduction. Seismic safety has become a critical component of every building and infrastructure project that is conducted in the areas of high seismic risk in this country, one that is considered from the very start of the project. Contrast this with wind hazard mitigation, which in most cases is not considered as a design priority and the building science professionals are not generally knowledgeable about it.

Ramping up funding levels for wind hazard mitigation research over the next several years and then maintaining it is the single most important step in building and filling a 'pipeline' of new design professionals that can solve the Nation's wind hazard problems. It will attract new faculty and graduate students to study in that area, leading to publications and textbooks and new courses that work their way into undergraduate curricula and continuing professional development for practicing engineers and architects.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Leslie Chapman–Henderson, President and CEO, Federal Alliance for Safe Home, Inc.—FLASH®

The information provided is based on our experience with input from many of the partners in the Federal Alliance for Safe Homes, including, but not limited to, our committee of technical construction experts and engineers from Georgia-Pacific, Home Depot, SkyeTec, the National Storm Shelter Association, State Farm Insurance Companies, Louisiana State University, Simpson Strong-Tie, Institute for Business and Home Safety, and WHYork Consulting. The retrofitting solutions that are referenced below have been tested through research at institutions including the University of Florida, Florida International University, and Texas Tech.

Questions submitted by Representative Phil Gingrey

Q1. What is the state-of-the-art for retrofit technologies of older construction?

A1. **State-of-the-art Retrofit Technologies—**Seven key methods of retrofitting older homes and protecting vulnerable areas have been researched and tested for their effectiveness. Today, these methods represent the best practices for state-of-the-art windstorm mitigation in the built environment. They include the following:

1) *Roof Deck and Attachment:* Install a roof deck of solid plywood five-eighths inches to maximize wind and wind-borne debris resistance with 10 penny common or eight penny ring shank nails spaced at six inches along the panel edges and every six inches in the field of the plywood panel. The nails must penetrate the decking directly into the roof framing, and a visual inspection from the attic should confirm that the roof decking is properly nailed to the roof framing.
2) *Secondary Water Barrier:* Create a secondary water barrier by installing self-adhering flashing tape or modified polymer bitumen strips on top of the joints in the roof deck. This measure keeps out the rain in the event the roof covering is damaged or destroyed by severe weather. Install a layer of 30# underlayment, or felt paper, over the decking and secondary water barrier. The felt helps with drainage in the event water gets under the roof covering.
3) *Roof Covering:* Install a roof covering that has been tested to the latest standards for wind and impact resistance. These standards are ASTM D 3161 (modified to 110MPH) or UL 2390 for wind resistance and UL 2218 for impact resistance. Adhesives can significantly increase the roofs resistance to uplift from the wind by applying a bead of premium construction adhesive inside the attic using a caulking gun along both sides of the intersection of the roof decking and the rafters or trusses. We recommend an adhesive that successfully meets APA AFG–01 or ASTM D 3498.
4) *Roof Shape and Bracing Gables Ends:* A hip roof typically performs better in windstorms than a gabled roof because of its aerodynamic properties and typical construction techniques. For gable end wall construction, there are two construction techniques that should be followed—Continuous Wall Construction, or Balloon Framing, and Platform Framing. Continuous Wall Construction uses full-height studs, concrete or solid masonry walls from the floor all the way up to the roof. Platform Framing is another option. Platform framing braces the intersection of the gable and the end wall as this intersection is a particularly weak point and those that are not properly braced can collapse. If the wall collapses, wind and wind-driven rain can enter the home causing major damage. In older homes with attics, an attic floor or ceiling diaphragm can be braced and retrofitted in some cases to provide the lateral support of the gable end wall if the end wall is not framed full height.
5) *Roof-to-Wall Connections:* To make sure the roof stays in place in high wind, securely anchor the roof to wall by installing hurricane straps or clips at every wall-to-rafter (or truss) connection to reinforce the roof. These connections are critical in holding the roof together and will dramatically increase the home's overall resistance to wind. The connectors should be installed under the manufacturer's specifications.
6) *Opening Protection:* Protecting home's openings such as windows and doors from penetration from wind-borne debris can be done by installing code-approved impact-resistant windows and doors or installing impact-resistant coverings, such as shutters over windows and doors. Impact-resistant glass

and shutters are specifically designed to meet a combination of impact from wind-borne debris and continuous pressure from the wind.

Impact resistant windows usually consist of a clear plastic-like film sandwiched between two specially-treated pieces of glass, giving the window greater strength than glass alone. Equally important as the strength of the glass is the strength of the window's frame. An impact resistant window is tested as a unit that includes the glass, the frame, as well as the attachment hardware and the installation method. A variety of products have been brought to market that have been tested to research-based standards and have been designated as such through a recognized product approval system or evaluation report. Recognized ratings include are SBCCI SSTD 12; ASTM E 1886 and ASTM E 1996; and Miami-Dade Protocols PA 201, PA 202, and PA 203.

7) *Doors:* Exterior doors should be wind and impact resistant or protected with an impact resistant covering. Garage doors are particularly vulnerable to high winds because of the long span of opening they cover and the relatively light weight material they are made of. Two options are available for the strengthening garage doors. One option is to replace the door track with a system that is designed to withstand high winds and wind-borne debris. The other is to protect the garage door with a tested and approved impact resistant covering.

Q2. What are the costs of those changes for an average house built in 1970?

A2. **Average Costs for Retrofit Technologies—**The information below shows estimated costs for improvements on homes built in 1970 or before using the retrofitting technologies for older homes. This data was collected through the My Safe Florida Home program, administered by the Florida Department of Financial Services, with actual retrofit numbers and pricing. In the course of conducting free wind inspections, My Safe Florida Home estimated that it examined 4,315 homes that were built in 1970 or before. The average age of all the homes inspected under the program in 2007 was 26 years, with an average insured value of $238,000.

Interior roof deck attachment (installed on the underside of the roof via the attic)—$3,754

Exterior roof deck attachment (installed when home is being re-roofed)—$201

Interior secondary water barrier (installed on the underside of the roof via the attic)—$4,527

Exterior secondary water barrier (installed between the roof deck and roof cover)—$784

Upgrading roof covering—$2,177

Bracing gable-end walls—$576

Reinforcing roof-to-wall connections—$1,823

Standard protection for entry door—$764

Standard protection for gable end vent—$84

Standard protection for garage door—$1,263

Standard protection for skylight—$739

Standard protection for sliding glass door—$1,611

Standard protection for window—$279

Permanently attached protection for entry door—$764

Permanently attached protection for gable end vent—$84

Permanently attached protection for garage door—$1,263

Permanently attached protection for skylight—$739

Permanently attached protection for sliding glass door—$1,611

Permanently attached protection for window—$723

Permanently deployed protection for entry door—$696

Permanently deployed protection for garage door—$1,263

Permanently deployed protection for skylight—$739

Permanently deployed protection for sliding glass door—$4,692

Permanently deployed protection for window—$1,771

Source: My Safe Florida Home Program

Original program cost estimates were established via a survey and analysis that looked statewide at pricing estimates for each retrofit option covered by the My Safe Florida Home Program. The pricing information was obtained from sources including:

- Garage door manufacturers and suppliers
- Impact-rated window manufacturers
- International Hurricane Protection Association data
- Data from Manufacturers of both standard and non-standard shutter products
- Local building contractors regarding specific retrofits such as soffit replacement, roof-to-wall connections, and gable end bracing
- Roofing Contractors and the Florida Roofing, Sheet Metal and Air Conditioning Contractors Association (FRSA) for roof covering prices for cost per square foot of openings for protection, roofing, and specified retrofits of wall or gable ends
- Department of Financial Services Statewide Construction Pricing List

As stated above, the My Safe Florida Home now uses actual grant costs on home improvements to maintain current cost estimates and uses data collected from approximately 400,000 completed home inspections performed from 2006 to 2008.

Q3. Can we confidently calculate the cost and benefits of retrofit technologies currently?

A3. **Cost Benefits Ratios for Retrofit Technologies—**We believe that we can confidentially calculate the costs and benefits of retrofit technologies currently available. One measure of financial cost benefit ratios may be established by calculating the savings to homeowners that may be achieved through the lower insurance premiums offered when a home's storm-resistance rating is improved. By law, all licensed insurance companies in Florida must offer discounts on premiums for hurricane-strengthening features. In a report released in February 2008, My Safe Florida Home reported that retrofitting an average home with $3,748 in improvements yielded an average discount on wind premiums of 24 percent. Of 393,446 homes inspected to date, 226,368—57 percent—were eligible for an average savings of $218 dollars off their wind insurance premium annually. Of all homes that were awarded grant funds to protect all openings, the average increase in strength to the home as measured by the hurricane resistance rating scale was 36 percent, or 16 points.

Another method of calculating costs and benefits is to conduct a statistical analysis of the economic and social losses that may be avoided through mitigation. These losses may include direct property damage, business interruption, human losses, and the cost of emergency response.

The Multi-hazard Mitigation Council (MMC) of the National Institute of Building Sciences released an independent study in 2005 that quantified the future savings from hazard mitigation, looking at hazard mitigation activities related to earthquake, wind and flood funded through three mitigation grant programs—the Hazard Mitigation Grant Program, Project Impact, and the Flood Mitigation Assistance Program. The study was in response to a mandate by the Senate Appropriations Committee, Subcommittee for the Veterans Administration, Department of Housing and Urban Development, and Independent Agencies of the 106th Congress (Senate Report 106–161).

The final MMC report, *"Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities,"* looked separately at earthquake, wind and flood mitigation, providing a cost-benefit analysis for each threat. The study considered both "project" mitigation—physical measures to reduce damage—and "process" mitigations—which include activities such as assessment, education and efforts to foster stronger building codes.

With regard to wind mitigation activities, the MMC findings were that property loss benefits can be significant, with reductions measuring up to four times the cost of the retrofit. The total benefit-cost ratio of wind hazard mitigation was 3.9—much higher than the 1.5 benefit-cost ratio of earthquake mitigation. The MMC study looked at community-wide benefits, taking into account impacts including human losses, economic loss, direct property damage, business interruption, and government costs including emergency response.

While existing data clearly points to a favorable benefit-cost ratio for wind hazard mitigation, there are areas that may be further explored in future efforts. Areas for further study may include a benefit-cost analysis specific to residential structures, estimating cost-benefit ratios for specific retrofitting measures or techniques. Relatively inexpensive measures to protect the integrity of structures may have enormous incremental benefits—for example, the loss of a roof in a windstorm can easily lead to a total loss of the structure, which may be prevented by a few relatively inexpensive retrofitting techniques.

Q4. If not, what needs to be done to improve our understanding?

A4. **Expanding Cost Benefit Information—**We believe that the current financial cost-benefit information, while reliable, can and should be expanded through ongoing efforts in all the states facing wind hazards as different local market conditions, construction costs and insurance regulatory laws can affect the cost and feasibility of wind retrofitting activities. This could be accomplished through expanded market level research leveraging the readily available data on actual improvement costs along with data collected on the age and resistance of the current housing inventories. These efforts could be expedited in hurricane-affected markets like Alabama, Mississippi, Louisiana and Texas. This additional market research would likely yield an enhanced picture of the current built environment and its vulnerability to the wind hazards including hurricanes and tornadoes.

Further, we urge the Committee to consider an investment in expanded applied research to support further refinement of retrofitting techniques. This investment in research and testing of construction techniques could introduce enhanced efficiency and cost savings that will positively impact cost benefit calculations.

Finally, we urge that cost benefit always be viewed, first and foremost, in the context of life safety and injury prevention while recognizing financial benefits as an essential but secondary benefit. The recent losses of thousands of lives as both direct and indirect outcomes of hurricanes and tornadoes are stark reminders of the essential nature of reducing windstorm threats at any cost.

We applaud the Committee for this critical examination. We thank you for your commitment to solving the critical issue of wind hazard reduction, and we are standing by if we may be of any additional service.

Appendix 2:

Additional Material for the Record

STATEMENT OF TIMOTHY A. REINHOLD
SENIOR VICE PRESIDENT OF RESEARCH AND CHIEF ENGINEER
INSTITUTE FOR BUSINESS & HOME SAFETY
TAMPA, FLORIDA

Chairman Wu and Members of the Subcommittee, my name is Dr. Tim Reinhold. I am the Senior Vice President of Research and Chief Engineer for the Institute for Business & Home Safety (IBHS), which is a nonprofit initiative of the U.S. property-casualty insurance industry dedicated to reducing property losses of all types. Our members write 87 percent of the property-casualty business in the country. Our research and mitigation messages are focused on earthquakes, wildfire, high-winds, hurricanes, freezing weather, and flooding. We are specifically involved in windstorm impact reduction through:

- research and testing;
- communications;
- outreach and education;
- building code development and adoption;
- data collection and analysis; and
- promotion of incentives for mitigation and disaster resistant construction.

Our members have clearly recognized the need for, and potential benefits of, significant new investments that target hazard-related research and focus on physical mitigation of buildings and structures. In response to that need, the IBHS Board of Directors this spring authorized construction of a major new independent research laboratory for which we are currently involved in a $40 million capital fundraising campaign. A central element of the laboratory will be a windstorm simulation facility capable of reproducing a variety of conditions ranging from hurricane winds and wind-driven rain, wind-blown hail, and wind-driven wildfire effects.

In addition, our members have voted to significantly increase our operating budget over the next few years. Beyond this direct investment in our own efforts, IBHS members clearly recognize the need for additional federal investments in basic and particularly applied research related to natural hazards and mitigation efforts. Specifically, IBHS as well as a number of our member companies have supported the "National Windstorm Impact Reduction Program" and IBHS provided testimony during the hearings that led to its initial authorization. It is unfortunate that no funds were ever appropriated for that program.

Risks and Vulnerability

Over the past decades, with the exception of Hurricane Katrina, we have seen dramatic drops in the loss of life during hurricanes due to better warning and evacuation systems. Warning times for tornadoes have improved in many parts of the country through the extended use of Doppler radar, and we are seeing increasing numbers of people being evacuated in areas threatened by wildfire. In contrast to the reductions in loss of life, we have seen dramatic increases in property losses as our nation concentrates more and more of its population and wealth along our vulnerable coastlines and in areas with greater risks for wildfires. It has been estimated that some 60 percent of the new homes built in the 1990s (about 8.4 million houses) were located in the Wildland Urban Interface (WUI), and are at increased risk of damage from wildfires. Furthermore, fully 50 percent of the U.S. population now lives within 50 miles of the coast, and one-third of housing units within the contiguous U.S. are currently located within the WUI.

As a result of this increased population density in vulnerable areas, we are certainly not immune to a large loss of life in a future hurricane event. Many experts are concerned that a fast developing and fast moving hurricane could produce a large loss of life among people trapped in traffic jams associated with attempts to evacuate too many people in too short a time. Ultimately, we are not likely to be able to provide enough evacuation capacity and warning time to handle the demands if population growth continues unabated. Many emergency managers would argue that we have already passed the point where mass evacuation is viable in many of the more vulnerable areas. We are also seeing large numbers of people being evacuated in front of fast-moving wildfires and have already reached the point where more people die on the roads trying to evacuate before wildfires strike than die in buildings that burn during the wildfires.

To counter the evacuation risks and the dramatic increases in property losses from hurricanes, we desperately need to build stronger and safer homes and businesses resistant to windstorm effects, including water intrusion. Stronger, storm-resistant buildings will mean that coastal inhabitants, who are not in vulnerable structures or in inundation areas where evacuation is mandatory, will not need to evacuate. In addition, property losses will be reduced and the resiliency of our communities will dramatically improve. Post-storm analysis of building performance following the 2004 and 2005 hurricane seasons has clearly demonstrated that modern engineering-based design of buildings is reducing structural damage and economic losses.

However, water intrusion and interior damage is still causing many people to be displaced from their structurally sound buildings. Unfortunately, the large inventory of properties built without any building code requirements, or using earlier inadequate codes, continues to dominate the losses whenever a storm strikes. Improved analytical tools and test methods are needed that will allow more cost-effective design for new buildings and that address water intrusion issues. Significant research is needed to address risks for existing buildings, which should include development of analytical tools and test methods to support both development and evaluation cost-effective mitigation measures.

Similarly, we need a better understanding of wildfire risks and better methods for predicting wildfire spread and community performance. There are clear indications from community assessments following recent wildfires that it is possible to design and maintain fire resistant communities. However, the assessment of risk factors still needs significant improvement. Current modeling efforts within NOAA, NIST, the U.S. Fire Service and academia need additional support. Again, the research should target the assessment of risks to existing buildings and the development of analytical tools and test methods that will support both the development and evaluation of cost-effective mitigation measures for individual properties and for community approaches to reducing risks.

Other types of windstorms, including strong thunderstorms and tornadoes, routinely represent a large portion of annual losses across our nation. While there are no clear indications that the total number of tornadoes or the strength of tornadoes is increasing, the expansion of urban and suburban areas means that the chances of a major storm affecting homes and businesses continues to increase. Building codes have tended to stay away from prescribing strengthening of buildings to resist tornadoes because the chance that a particular building will be struck are below the risk threshold usually used by building codes to prescribe minimum design requirements. Key goals for personal protection can be expressed as creating a safe place and providing time to get there before a tornado strikes. Nevertheless, some high-value properties are being specifically designed with these events in mind, and the International Code Council recently developed a shelter design standard that addresses design of both tornado and hurricane resistant shelters. The potential for large tornadoes to affect large portions of communities or a whole community have been driven home in recent years by the Oklahoma City tornado and the Greenburg, Kansas, tornado.

When it comes to the general population of buildings, there are clear indications that modest strengthening of connections could reduce structural damage in the more frequent weaker tornadoes. About 87 percent of the land area affected by tornadoes or other thunderstorm-related wind events experience nominal wind speeds below those associated with a moderate hurricane. Even the most intense EF–4 or EF–5 tornadoes produce large variations in wind speeds, with significant areas around the periphery of the storm being affected by lower wind speeds. There are clearly differences in the wind structure of these storms. NOAA and NOAA/NSF funded academic research to investigate the structure of these storms is needed. NIST and NSF funded research is also needed to investigate the corresponding wind-structure interaction. This research is needed to assess the implications for design of building components, connections and systems when additional protection is desired.

Experience over the past several decades and projections for the future all indicate that damage and losses from hurricanes, tornadoes and wildfires are all expected to increase. Most of that growth is related to increased concentration of population and property values in risky areas. Improvements in the design and construction of new homes and communities, and the implementation of mitigation measures for existing buildings and communities, are the most effective means for actually decreasing the losses and impacts on communities. Improved predictive tools for communicating risk and for providing advance warning so that last-minute preparations can be taken and safe evacuation accomplished also play an important role.

Mitigation Research

As indicated above, a major emphasis of future research should be on developing improved predictive tools and test methods that address the specific characteristics and risks of each of the hazards. Progress has clearly been made in defining general problems and vulnerabilities; but, as we move to the level of a specific community and then to a specific structure, predictive tools lose their ability to address specific vulnerabilities, to assign loss estimates to those vulnerabilities and to establish clear cost-benefit estimates for mitigation measures.

In order to better assess various mitigation measures and to establish priorities, significant research is needed that will enhance existing or develop new test methods, analytical tools and system approaches to integrating the vulnerability assessments. Given the state-of-the-art, I would suggest an almost equal investment of resources in short-term and long-term efforts. There will have to be a coupling between knowledge gained from research into the nature of the risks with analytical tools and test methods to assure that the salient physical factors are adequately included.

Parallel efforts can be effective. We need to revisit and carefully review current test methods and analytical tools in light of recent observations from post-event assessments. This will assure that any limitations and possible relationships between laboratory or computer simulations and field experience are clearly defined. At the same time, additional research is clearly needed on the nature of the threats posed by the different hazards and of the physical characteristics that are potentially important to performance of buildings when they are exposed to the hazards.

A major emphasis of the research should be directed towards system effects and system performance so that the roles of various vulnerabilities can be properly assessed within an overall performance-based analysis. The research should focus on more complete definition of the phenomenon involved in the basic hazards and on the interaction of those hazards with the built environment. Initial high-level assessment and tools can help in the short-term, but ultimately, the assessments and tools must be built upon a very granular foundation that properly accounts for individual elements within the context of the system performance.

Case studies and demonstration projects, similar to those employed in building energy research, should be a part of the program. Durability and performance in extreme events after years of exposure to the elements must be factored into assessment of products and systems. We must move beyond assessments that are limited to new unused products and account for the effects of aging.

Much of the private industry research and development as it applies to wind hazards has focused on meeting existing test standards so that products can obtain product approvals necessary to allow their use in building construction. There are some ongoing efforts to look at new test methods and performance issues within government laboratories and academic institutions and to some extent by industry associations.

Implementation of the National Wind Impact Reduction Program

In a real sense, the National Wind Impact Reduction Program (NWIRP) has never been implemented in any meaningful way because no funds were ever appropriated for the program. Nevertheless, there has been some progress in windstorm-related research through activities of individual agencies using existing authority and budgets and through several earmarks that have directed budgeted resources to academic organizations at the expense of agency activities and priorities. Significant advances include the measurement of meteorological parameters in hurricanes, around the periphery of tornadoes, and in wildfire regions and in improving the understanding of wind loads and wind effects. However, these efforts have been fragmented and of limited scale due to lack of resources. Consequently, they have generally not provided the level of detailed information needed to significantly improve our understanding of all of the important parameters or significantly improve assessment tools or modeling of the events.

Some specific examples are described below. FEMA has produced a series of best practice documents following some of the major hurricanes and other windstorm events and has developed a powerful general risk assessment tool through HAZUS–MH. However, significant work is still needed before it will be particularly useful for evaluating individual properties. NIST has been working on a database assisted tool for improving the assessment of wind loads on structures that should be an important resource for improving load definitions in future editions of the model building codes. NIST also has been working on a detailed model of wildfires that includes the kind of detailed granular structure needed to create a useful predictive tool. Again, this tool may have its greatest use in improving future wildfire related building code requirements and in the assessment of mitigation measures.

NIST-related earmarks have funded research initiatives at Texas Tech University and for one year at a consortium of universities that included Clemson University, the University of Florida and Virginia Tech. The research conducted through these earmarks have contributed to improved understanding of wind loads and wind characteristics that are beginning to find their way into proposed building code changes. The NSF has funded a number of research initiatives, including one through PATH funding that has targeted water intrusion research. NOAA has been continuing its work on forecast enhancements and through earmarks has funded some of the land-based deployments of instruments to measure wind conditions in hurricanes. The National Sea Grant Program of NOAA also has funded a number of research efforts aimed at improving the resilience of coastal properties and the evaluation of mitigation options for existing buildings.

There has been some level of coordination of these various research activities between individual agencies and in particular between researchers at the various agencies. For example, NSF has funded the water intrusion research through funding associated with HUD's PATH program using jointly established priorities. NIST is working with NOAA and with the U.S. Fire Service on its modeling of wildfire risks. However, there has not been the level of coordination originally envisioned by a fully developed and fully funded NWIRP.

As Congress looks towards reauthorization of the NWIRP, we would suggest that it concentrate the efforts in three areas.

- The first is development of enhanced understanding of the events, including better definition of parameters that are important to the design and performance of the built environment. For hurricanes, this can include ability to forecast tracks and intensities of events, but it should go beyond that to include characterization of storm characteristics such as wind turbulence, gust structure, and wind-driven rain characteristics and quantity. For wildfires, it would include the influence of topography and terrain roughness on the local wind climate, turbulence associated with the flow, and influence of burning vegetation and houses on winds in a community. For tornadoes, it could include better definition of the wind field near the ground surface.
- The second area is research directed at better understanding and modeling of the interaction of the events with the built environment. For hurricanes, this would include the influence of wind characteristics and water droplet size distributions on wind loads and water intrusion, respectively. For wildfire, it would include the influence of wind on ignition points, fire intensity and heat transfer, as well as the ability of firefighters to influence the risks. For tornadoes, it would include the influence of the wind field characteristics on wind loads and a better understanding of the required strength of components and connections to resist these loads and effects.
- The third area is the research aimed at improving building codes, developing effective mitigation measures and analysis tools to improve design efficiency as well as assess the benefits of mitigation measures or design requirements on both component and system performance. This research also should target the resilience of transportation and lifelines systems as they are essential to the quick recovery of individuals and communities.

We would suggest that the legislation designate a lead agency and provide more balance in the suggested funding that will emphasize the mitigation-related research efforts. Ultimately, we need to reduce the losses and disruptions that accompany these events in order to protect our citizens and stabilize our communities and economy. The NWIRP should have as its core focus activities which support that mission. Consequently, from our perspective, NIST should be the lead agency but funding and coordination should extend at least to NOAA, NSF, FEMA, HUD and the FHWA.

Technology Transfer

The main obstacles to widespread implementation of windstorm mitigation techniques in new and existing structures relate directly to issues of complacency, education, research and demonstration of cost effectiveness of the measures. Throughout the country, homeowners are, in general, complacent about their exposure to extreme windstorms or they believe there is little that can be done to provide protection from the most intense storms where people frequently are killed or injured. People who live in central Florida have typically said that the real risk is in South Florida, or the Panhandle. Likewise, builders and legislators who live and work in the Florida Panhandle think that they are protected by a shelf of cooler water off their coast and that the real risk in the Keys or in the Carolinas. A major problem is that the typical return periods between major storms is such that people do not think it will happen to them.

Because of this low perception of threat from windstorms, consumers are less likely to spend the money required to make their homes more resistant to windstorms—especially when they can spend their money on upgrades they can enjoy everyday like granite counter tops and hardwood floors. The competition to spend extra money on home improvements rarely results in mitigation efforts winning out. There is a fundamental need to create reliable tools that will provide accurate estimates of the benefits of mitigation measures as well as the costs. There is also a critical need for social science research to help guide the mitigation programs so that solutions are also implemented.

Lack of data and research on the benefits of mitigation and strong building codes also poses a barrier to the implementation of mitigation measures. The data that insurers collect as a part of the claims process following a major wind event relates mainly to documenting the damage that the policyholder needs compensation for and making sure the insured is compensated according to the policy coverage in a timely manner. The role of the insurance adjustor in such a scenario is to document, estimate and pay or arrange for payment of covered expenses. Typically there are extreme time constraints placed on the adjustors and the companies they represent to review properties and act on claims in a short timeframe. Given these responsibilities, it becomes too onerous (particularly in a catastrophe when large amounts of disaster victims need to begin their recovery) to expect that the adjustor would be able to determine and document the actual causes of loss and identify mitigation measures that could have prevented or reduced the damage. Because of this, insurance data alone provides little insight into the impact that wind mitigation can have on total losses.

In order to produce meaningful data to assess the effect of windstorm mitigation activities, several things need to be known. First, the actual wind speed and the characteristics of the wind that the building was exposed to needs to be known. Then, details as to what parts of the building failed due to excessive wind force need to be documented and most probable causes of initiation of failure need to be identified. By comparing the wind speed with a careful study of the failures, researchers can begin to make credible quantifications of the potential benefits of windstorm mitigation.

Unfortunately, many of the NOAA Automatic Surface Observing Systems (ASOS) lose power and stop recording or reporting wind speed data during severe wind storms. There is a clear national need to harden these systems and provide backup power so that NOAA and all those affected by these storms have better data on surface winds in various areas impacted by the storms.

A number of barriers to constructing stronger and safer structures also relate to the adoption and enforcement of building codes and standards.

- First, a large number of local communities throughout the Nation have not adopted any building codes and standards for residential construction.
- Second, a large majority of local communities have not adopted the latest model building codes without any local amendments that weaken the model provisions.
- Third, while there is more widespread adoption of model building codes and standards for commercial properties, there are again many local jurisdictions where code adoption is non-existent or woefully out-of-date.

Uniform and strong enforcement is another key issue, even in local communities that have adopted the latest standards. This lack of uniformity in the baseline for construction of homes and businesses means that the performance of buildings is less predictable and the levels of risk vary dramatically from jurisdiction to jurisdiction. We find that responsible builders have difficulties competing in areas where there are no building codes, which leads to building to the lowest denominator. Furthermore, we see national builders building differently in areas with identical design wind speeds, simply because the local building code adopted in a particular area does not require the same level of construction as the national model building code being enforced in the other area. All too often, the local building code is treated as the maximum rather than the minimum.

While issues of States' rights and local authority generally keep federal agencies from trying to mandate building codes, except for federal buildings, there are opportunities for the Federal Government to initiate a number of incentives that would encourage states to adopt and enforce statewide building codes without local amendments that weaken the minimum requirements. For example, FEMA could use the adoption and enforcement of statewide building codes as criteria for providing additional pre- and post-disaster mitigation funds to states. Federal mortgage agencies could provide lower interest rates or lower fees for mortgages on properties built to the latest building codes and standards.

Finally, many of the test and evaluation methods available for assessing the windstorm performance and durability of materials, components and systems fall short in reproducing the true nature of the loads and effects of severe windstorms and/or the effects of environmental factors on aging and associated degradation of windstorm resistance. Federal agencies can play an important role in funding research and developing facilities that will allow the more realistic simulation of windstorm loads and effects, and in the development of tools and facilities for assessing the effects of aging. Some efforts along these lines have been supported through the Partnership for Advancing Technology in Housing (PATH) through research and grants initiated by the National Institute for Standards and Technology and the National Science Foundation. Much more work is needed.

Conclusion

Windstorms and other natural disasters happen every year in the United States, and impact thousands of homeowners and businesses. Yet we do know how to build homes and commercial structures so that the losses and damage caused by natural disasters are significantly reduced. Ongoing research teaches us more every year, and ongoing communication and public education has the potential to reduce losses every year. All of the stakeholders can contribute to the creation of a climate where hazard resistant construction is valued and demanded and where a myriad of incentives are offered that will encourage local communities and states to build hazard resistant communities that become known for their resiliency in the face of severe windstorms or other natural and manmade hazards.

There are clear opportunities for the Federal Government to support research and the removal of barriers to the development of hazard resistant construction. We believe that the best road forward is through a coordinated multi-agency research initiative with significant new funds under the umbrella of the NWIRP.

Thank you very much. I would be happy to answer any questions you may have.

BIOGRAPHY FOR TIMOTHY A. REINHOLD

Tim Reinhold joined the Institute for Business & Home Safety in 2004, as Director of Engineering and Vice President. He was promoted to Senior Vice President of Research and Chief Engineer in 2008. Prior to joining IBHS, Dr. Reinhold was a professor of Civil Engineering at Clemson University for 12 years.

His professional career includes ten years as a consulting engineer with firms in the U.S., Canada and Denmark, and five years at the National Institute for Standards and Technology. He earned BS, MS and Ph.D. degrees in Engineering Mechanics from Virginia Tech in 1973, 1975 and 1978, respectively.

Dr. Reinhold has conduced research on wind effects and structural resistance for most of his professional career. In addition to directing numerous studies to determine wind loads for tall buildings and specialty structures, he has been heavily involved in research relating to the performance of housing and low buildings in hurricanes and other severe wind events.

His research includes post event assessments, model and full-scale laboratory studies, and in situ field structural testing. Dr. Reinhold serves on the American Society of Civil Engineers ASCE 7 Committee, the ASCE 7 Wind Loads Subcommittee and the ASCE 7 General Requirements Subcommittee.

He also served for about eight years on the Southern Building Code Congress International (SBCCI) Wind Load Subcommittee and is currently a member of the Board of Directors for the American Association for Wind Engineering. He has authored or co-authored numerous journal papers, chapters of books and conference publications.

The University of Oklahoma

COLLEGE OF ATMOSPHERIC AND GEOGRAPHIC SCIENCES

July 29, 2008

Rep. David Wu (D-OR), Chairman
House Technology & Innovation Subcommittee
House Science & Technology Committee
2320 Rayburn House Office Building
Washington, D.C. 20515

Rep. Phil Gingrey (R-GA), Ranking Minority Member
House Technology & Innovation Subcommittee
House Science & Technology Committee
H2-389 Ford House Office Building
Washington, D.C. 20515

Dear Chairman Wu and Ranking Member Gingrey:

On behalf of the University of Oklahoma we appreciate the opportunity to submit the following comments for inclusion in your Public Record regarding the July 24th, 2008 House Subcommittee on Technology and Innovation hearing on "The National Windstorm Impact Reduction Program….Strengthening Windstorm Hazard Mitigation".

Included in Public Law 108-360, October 25th, 2004, is Title 2 relating to windstorm impact reduction which is the subject of your Subcommittee hearing. We understand that Section 203 (4) defines windstorm as to include tornadoes with other destructive wind components. In addition the public law provides for various objectives by four agencies one of which is the National Oceanic and Atmospheric Association (NOAA) to "……support atmospheric sciences research to improve the understanding of the behavior of windstorms and there impact on buildings, structures, and life lines" (Section 204 (c) (3)). We therefore in our comments wish to focus on the tornado aspect of windstorm impacts and to assist the subcommittee in better understanding major research projects that are underway in Norman, Oklahoma in collaboration between the University of Oklahoma and the National Severe Storm Laboratory (NSSL).

We concur with the statements made by you and your colleagues at the hearing that the loss of life and destruction of property from severe weather takes a major toll throughout the United States. Attached to our testimony are several graph documents indicating the extent of tornado activity in the United States and its increase from previous years.

The University of Oklahoma is committed to continue our long standing research in severe weather phenomena and to support NOAA's National Severe Storm Laboratory in its weather related advanced warning projects. Established in 1964, the National Severe Storms Laboratory leads the way in investigations of all aspects of severe and hazardous weather. NSSL is part of NOAA Research and the only federally-supported laboratory focused on severe weather. The Lab's scientists and staff explore new ways to improve understanding of the causes of severe weather and ways to use weather information to assist National Weather Service forecasters, as well as federal, university and private sector partners. Early on, NSSL researchers recognized the potential of Doppler radar to improve the detection and warning of severe weather. NSSL built the first real-time displays of Doppler velocity data, which led to discoveries of tornado-related radar "signatures." The successful demonstration that Doppler radar could help forecasters provide much improved

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severe thunderstorm and tornado warnings led to the deployment of the Next Generation Weather Radar (WSR-88D) network of Doppler radars throughout the United States. NSSL continues to be a pioneer in the development of weather radar and detecting advanced severe weather such as tornadoes.

NSSL researchers are adapting state-of-the-art radar technology currently deployed on Navy ships for use in tracking severe weather. Phased Array Radar reduces the scan or data collection time from five or six minutes to less than one minute, potentially extending the lead time for tornado warnings beyond the current average of 12 minutes to a possible 45 minute warning. A National Weather Testbed has been created at the NSSL to continue research on Phased Array Radar. Attached to this statement is a more detailed discussion on the aspects of this new technology that can provide advanced warning. In addition, the University of Oklahoma is supporting research in another weather radar system entitled the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA). Detailed information on this important component in detecting the formation and tracking of tornadoes is also attached to our statement.

Both PAR and CASA radar research projects are a few of the many now underway at NSSL and OU, which can lead the way in the 21st Century, to upgrade the present NEXRAD system. This will have a dramatic and we believe positive effect on preventing injury and loss of life within areas impacted by tornadoes through advanced warning of approaching changes. Whereas today's warning time of 12 minutes has been widely accepted as adequate to find shelter within a structure as the approaching tornado or destructive wind approaches, if the structure is destroyed then lives as well as property will be lost. In fact most death and injury occur within homes or buildings that were destroyed. Phased Array Radar and CASA hold the promise, once research and development is completed of potentially offering 45 minutes to an hour warning for residents, perhaps giving enough time for evacuation of their homes or schools to other places away from harm. This new technology will also be instrumental in showing the path of the tornado so as to avoid its impact. These are issues that require further study and we urge the Subcommittee to consider supporting this recommendation.

Finally, we would like to commend the Subcommittee for holding this hearing and to calling attention to the need for further research such as that being conducted by the NSSL and other government institutions across the country. We are available to assist the Subcommittee and to demonstrate these technologies in Norman, Oklahoma should you or your staff wish to visit at any time.

Sincerely,

John T. Snow

John T. Snow
Dean, College of Atmospheric and
Geographic Sciences

JTS/las

Wind Storms and Tornadoes:
Early Detection and Warning made possible using CASA and MPAR Weather Radar

The National Science Foundation (NSF) and National Oceanic and Atmospheric Administration (NOAA) are supporting research and development for more advanced warning detection of tornadoes and other windstorms at the University of Oklahoma and the National Severe Storms Laboratory (NSSL) in Norman. Two ongoing projects are underway that could significantly bolster the National Windstorm Impact Reduction Program (part of PL 108-360). The Multi-function Phased Array Radar (MPAR) is a federally supported program designed as a replacement for NEXRAD that rapidly and adaptively scans the mid- and upper levels of the atmosphere. The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is an NSF-supported project designing networked radar systems that rapidly and adaptively sample the lowest levels of the atmosphere. Together, these programs are expected to significantly increase severe wind and tornado warning lead times, enhance forecast accuracy, and thereby improving public safety and mitigation of storm damage losses.

The Multi-function Phased Array Radar (MPAR)

Background

A National Weather Radar Testbed in operation in Norman (Zrnic et al. 2007) for a planned Multi-function Phased Array Radar (MPAR; Weber et al. 2007) already has demonstrated the capability to scan the atmosphere surrounding it by as much as four times faster than current operational radars (Figure 1), to dwell on individual windstorms to monitor rapid changes using agile beam technology, and to perform aircraft surveillance (Figure 2). Early detection of rapidly-developing hazardous windstorms requires rapid-scan radar. The testbed supports adaptable scanning strategies and scans storms volumetrically in time scales of seconds instead of several minutes. Such high temporal sampling provides unprecedented opportunity to detect and examine rapidly evolving weather phenomena and to explore the potential to extend warning lead-time.

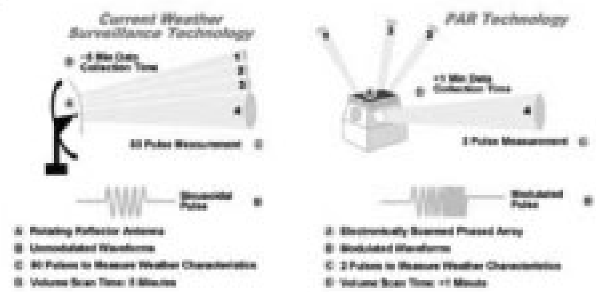


Figure 1. Basic differences between conventional weather radar (left) with a mechanically-rotating antenna and an agile-beam phased array radar.

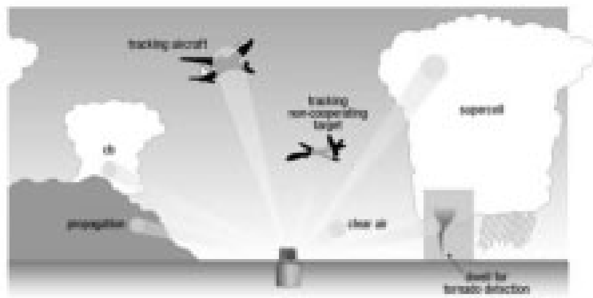


Figure 2. This MPAR schematic illustration shows from left: full-volume continuous scan through a developing cumulonimbus cloud, full-volume continuous scan through the planetary boundary layer (clear air) for mapping winds, detection and tracking of aircraft including non-cooperative targets, full-volume continuous scan through a supercell storm, and long-dwell scan through a region of a potential tornado.

A Joint Action Group of Federal departments and agencies, coordinated by NOAA's Office of the Federal Coordinator for Meteorology (OFCM) has indicated great potential for MPAR technology to upgrade existing radar systems, including the WSR-88D weather surveillance radar network. Present weather radar is limited in meteorological terms by insufficient spatial resolution and temporal update rates when monitoring some weather phenomena and inability to directly measure many atmospheric variables that are needed to meet anticipated measurement requirements. The desirability of the phased array radar system rests in its expected order of magnitude improvements in critical capabilities such as data timeliness, resolution, and availability, which will allow for faster scanning strategies of the middle and upper parts of storms, where rotation and damaging downbursts often form, that are expected to significantly increase warning lead times. Ongoing research and development, with multi-function applications, is expected to lead a potential savings to taxpayers of $2 billion in acquisition costs and an additional $3 billion in operations and maintenance costs over a 30-year period by utilizing one multi-function radar network that can provide the same coverage available today from several weather and aircraft surveillance networks, but with 40 percent fewer radars.

Importance of MPAR for Windstorms

Since the term "windstorm" in the National Windstorm Impact Reduction Program's language is defined as "any storm with a damaging or destructive wind component, such as a hurricane, tropical storm, tornado, or thunderstorm," this definition could include hurricane-embedded tornadoes that may increase hurricane winds by 100 miles per hour in isolated places, destructive straight-line winds and microbursts produced by severe thunderstorms, and wind-driven water such as heavy rain and hail. All of these phenomena could be better monitored and understood with faster-scanning radar that has the ability to dwell. Two particular areas within the

Windstorm Program that the MPAR could help address are "improved data collection and analysis" (through its faster scanning strategies) and "improve the understanding of the behavior of windstorms" (through collection of more detailed data in time and space that will allow research on phenomena not yet well understood using today's data). Both of these contributions would bolster the Program's overall objective of "achievement of measureable reductions in losses of life and property from windstorms." Reductions in losses of life and property relate directly to reduction in risk to the windstorm hazard, with reduced risk coming from better understanding and prediction of the hazard. In particular, among the research questions that could be answered by MPAR's inclusion in the Windstorm Program could include verification that a faster refresh rate, together with multiple beam techniques, longer dwell times on storm areas of interest, and new knowledge gained on storm morphology, can lead to improved conceptual understanding of storm evolution and storm modeling, and ultimately to tornado and other windstorm warnings.

Needs for Frequent Observations

The MPAR offers benefits to both research and operations. Frequent volumetric data provided with the radar are needed for observations of short-lived phenomena like violent windstorms and "assimilation" into storm-scale numerical weather prediction models that may allow a new paradigm in storm warnings known as "warn on forecast" (Figure 3).

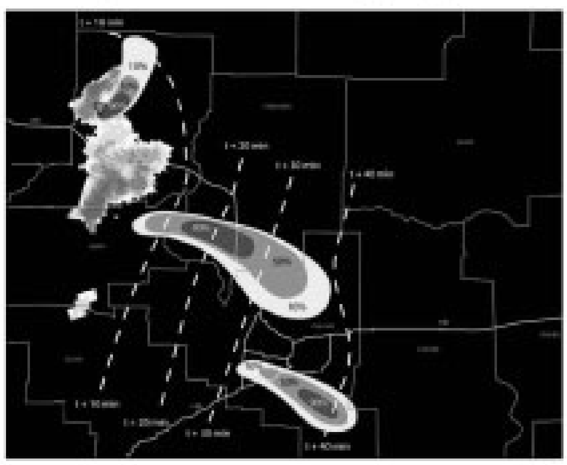


Figure 3. MPAR may enable a new paradigm called "warn on forecast" that allows average tornado lead times to be extended to 45 minutes by issuing warnings based on forecasts from earlier precursor conditions.

Observation of short-lived hazardous phenomena. The MPAR is well suited for repetitive rapid observations of hazardous weather phenomena like windstorms. High temporal resolution data in real time offer immediate and tangible societal benefits through improved hazard warning (e.g., microburst/straight-line wind and mesocyclone/tornado detection), nowcasting, and guidance for aviation operations. Past research has demonstrated that, on the average, lead times for microburst detection increase from about 2.2 minutes (at 3-minute observation updates) to 5.2 minutes (at 1-minute observation updates). Additionally, rapid high-resolution measurements can potentially aid in the formulation and verification of theories of tornadogenesis – our basic understanding about how tornadoes form. Past NSSL observations of the Dimmitt, Texas, tornado of 2 June 1995, with an airborne Doppler radar revealed that the time scale for tornadogenesis was exceedingly small (less than 80 seconds). This rapid evolution is impossible to observe with conventional scanning radars that refresh every several minutes. To fully detect the process of tornadogenesis, scan times of roughly 20–30 seconds are required in a relatively small volume crucial for spawning the tornado.

Fast adaptive scanning. MPAR beam agility permits fast adaptive scanning and signal processing to match the weather situation (refer back to Figure 2). This means MPAR can vary its focus and emphasis over different parts of the scan volume, for example, dwelling longer on regions of a storm where tornadoes are likely to form. It can also frequently revisit critical regions to track the rapid evolution of severe and hazardous phenomena, including tornadoes. Frequent measurements of meteorological hazards (e.g., tornadoes, microbursts, hailstorms) can lead to better warnings and predictions of the trends in these phenomena.

Initialization of cloud and storm-scale numerical prediction models. A further application of more frequent three-dimensional radar data is in the initialization of storm-scale numerical weather prediction models. Assimilation of clear-air boundary layer data in cases where sea-breeze fronts, inland fronts, or boundaries from preexisting convection are present may improve the timing and location of convective initiation, a *key problem* in the numerical prediction of severe weather. In addition, assimilation of radar data and derived fields when convective weather is already present can potentially reduce the pervasive "spin-up" problem in numerical weather prediction; that is, reduce the time needed for model physics to generate realistic convective elements within non-convective background fields. Past work has shown that assimilating volumetric data from a single virtual radar at 1-minute intervals provided significantly better analyses and forecasts than assimilations with less frequent updates of 2.5 or 5 minutes.

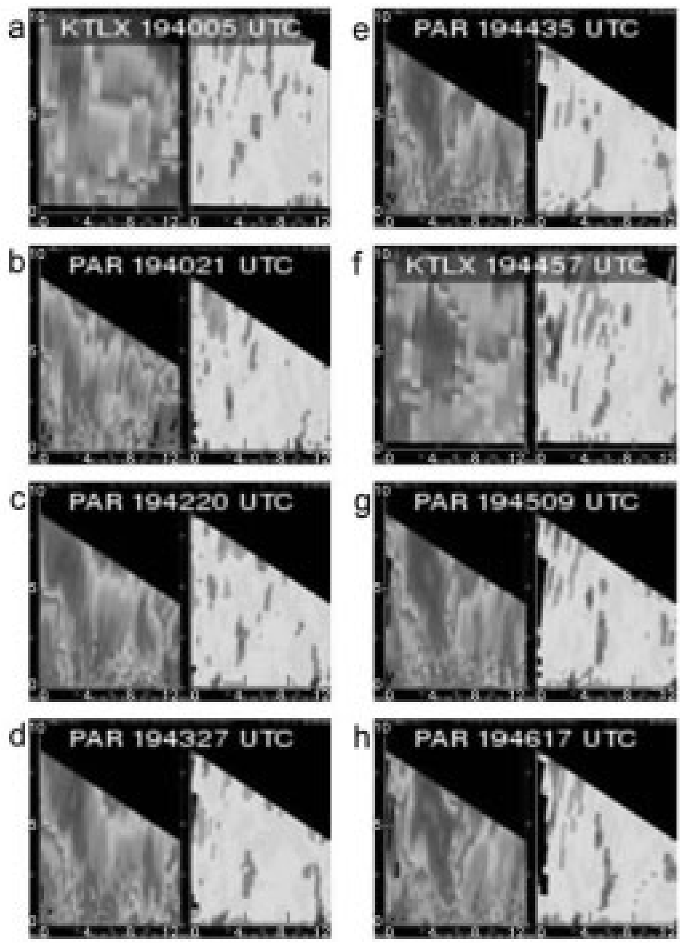
Demonstration of the MPAR's Testbed Radar to Monitor a Severe Windstorms

Tornadic storm. At 2048 CDT 29 May 2004, a tornadic storm developing close to the testbed radar provided a good opportunity for collecting data. The reflectivity field exhibited a classical hook echo. In Figure 4, a sequence of images obtained by the NWRT is contrasted with two consecutive images obtained with the nearby WSR-88D. Circled are three couplets of strong shear (rapid change in wind direction in a small area) in azimuth. At the beginning of the sequence (top) the middle couplet is clearly a tornadic vortex signature (TVS), the northern one is marginally strong, and the southern one is a weak anticyclonic shear. On the rapidly updated data of the testbed radar it is evident that the anticyclonic shear intensifies into the TVS;

furthermore, during these four minutes the northern shear weakens and almost dissipates. These rapid evolutionary changes are missed in scans spaced by 4 minutes as seen on the display of the WSR-88D data. The storm was subsequently tracked as it produced several tornadoes during its lifetime.

Figure 4. Radial velocity fields obtained with the WSR-88D radar in Oklahoma City and the MPAR testbed in Norman. Times of observations are printed as is progress from top to bottom. White circles mark tornadic vortex signatures. This tornadic storm occurred on 29 May 2004.

Microburst. Heinselman et al. (2008) demonstrated the utility of the MPAR testbed during a microburst. Figure 5 shows data from the 4 KTLX (Oklahoma City WSR-88D) volume scans and 16 MPAR testbed volume scans that illustrate the temporal evolution of the event. Each panel shows the vertical profile of reflectivity (left) and linear least square derivative LLSD radial divergence. The LLSD radial divergence field is typically very noisy outside of storm regions, but within a storm region it is useful for identifying areas of convergence and divergence. Because the storm is rapidly scanned by the electronically steered PAR beam, the temporal evolution of the entire storm cell is more fully sampled and rapidly changing features are not missed between volume scans. As can be seen, the microburst is more fully sampled in time; the authors strongly suspect that the illustrated high resolution sampling of microburst precursors will support the development of prediction algorithms with higher accuracy than convectional radars.


a
KTLX 194005 UTC
b
PAR 194021 UTC
c
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KTLX 194457 UTC
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PAR 194617 UTC

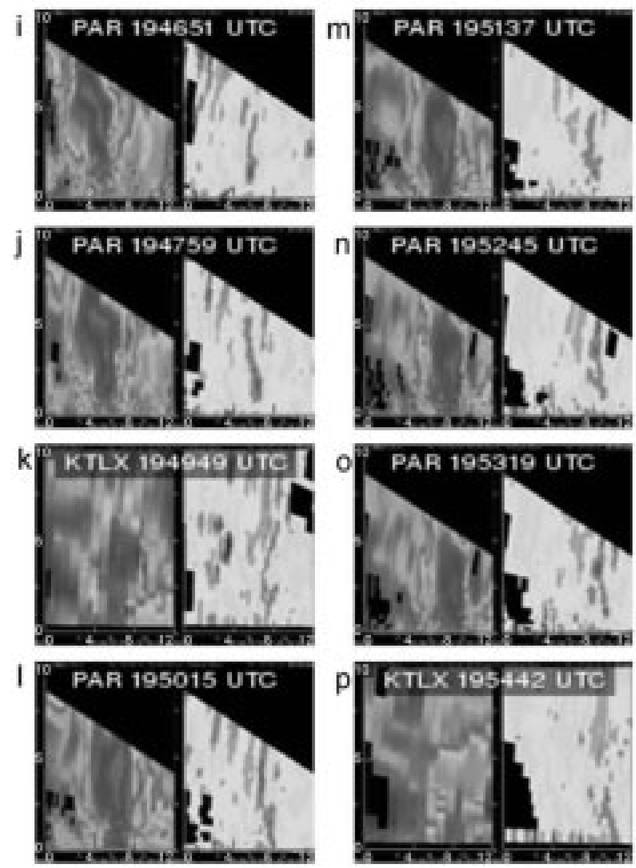

Figure 5. A time series of PAR (Norman) and KTLX (Oklahoma City) WSR-88D data showing the evolution of a strong microburst event on 10 July 2006 (a–t). Each panel shows the vertical cross section of reflectivity (dBZ, left) and radial divergence (s^{-1}; right)

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The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA; Brotzge et al. 2006) is a multi-year Engineering Research Center, funded in 2003 by the National Science Foundation for the development of small, inexpensive, low-power radars designed to adaptively scan the lowest levels (< 1.5 miles AGL) of the atmosphere, with the end goal of increased tornado and severe storm warning lead time and improved forecasting capability. CASA is a multi-university partnership comprised of the University of Massachusetts (lead institution), the University of Oklahoma, Colorado State University and the University of Puerto Rico at Mayaguez. CASA is joined by several dozen state and federal government agencies and private sector companies, including NOAA and the National Weather Service, that actively collaborate through CASA's industrial partnership program.

Current radar technology scans too slowly, has resolution that is too coarse, and misses much of the lower atmosphere for the proper detection, monitoring and forecasting of severe wind events and tornadoes. To address these issues, a prototype network of CASA radars was deployed in fall 2006 in southwestern Oklahoma. Radar data from this testbed yields overlapping beam coverage at high spatial and temporal resolution, providing 3D images of storm structure updated at least once per minute. Several cases have now been collected that demonstrate the value and improvement in detecting, monitoring, and forecasting hazardous severe wind and tornadoes using CASA radar technology.

Current Technology

The severity of hazardous weather can be defined by its intensity, horizontal scale, and duration. Severe, straight-line winds and tornadoes contain the most intense winds on earth, and the strongest tornadoes can last well over an hour. Though relatively small in area, it is precisely these small dimensions of severe downbursts and tornadoes that make early detection and warning of these hazards much more difficult.

The implementation of the Weather Surveillance Radar – 1988 Doppler (WSR-88D) network during the early 1990s improved detection and advanced warning of these severe wind hazards (Simmons and Sutter 2005). Average tornado warning lead time is now 13 minutes, and three-quarters of all tornadoes have advanced warning. Despite these improvements, however, nearly

25% of all tornadoes remain unwarned; in the western U.S., over 40% of tornadoes are not warned. Severe downburst winds also remain a significant forecast problem for many Weather Forecast Offices (WFOs); one WFO from the Intermountain West recently commented that their worst verification statistics were from downburst winds, which threaten public safety and cause damage to property and livestock.

Many tornadoes and severe winds are not observed with today's WSR-88D weather radars because of three inherent limitations. First, WSR-88D radars are sparsely distributed, spaced on average several hundred miles apart. Because of earth's curvature beneath the radar beam, the further one moves away from the radar, the higher the radar beam is above the ground. At 75 miles distance from a radar, the radar beam at 0.5 degree elevation (the lowest elevation angle of the WSR-88D) is approximately 1.2 miles above the ground. Thus, low-level severe winds and tornadoes are not observed at these distances. Second, current radar technology scans mechanically, requiring 4-6 minutes to conduct a full volume scan of the atmosphere. Third, WSR-88D radars scan in fixed volume coverage patterns (VCPs); thus, they are unable to quickly adapt to rapidly changing storm evolution. New CASA radar technology addresses these radar limitations with a dense network of radars, each with rapid, adaptive and collaborative scanning capabilities.

CASA Technology

CASA radars are designed to operate as a network, collectively adapting to the changing needs of end-users and the environment; this network approach to scanning is known as *Distributed Collaborative Adaptive Sensing* (DCAS; McLaughlin et al. 2005). DCAS improves data quality and maximizes the utility of each scanning cycle (Philips et al. 2007). A testbed of four prototype CASA radars were deployed in southwestern Oklahoma in 2006 and operated continuously while in DCAS mode during March through June of 2007 (Brotzge et al. 2007; Chandrasekar et al. 2007) and again during spring 2008.

When dealing with severe wind storms and tornadoes, operational forecasters must deal with two issues: 1) Monitoring the real-time initiation and development of severe wind and tornadoes (also known as *nowcasting*); and 2) Prediction of the development and path of severe wind events and tornadoes, prior to formation. CASA radar technology has demonstrated improvement in both the nowcasting and prediction of severe wind events.

Nowcasting: Real-Time Detection and Tracking

Severe Straight-Line Winds

CASA radars have several advantages over other radar technologies for detecting and monitoring severe straight-line wind events. First, CASA radars are scanning the lowest levels of the atmosphere. Velocity measurements made at these low level heights better represent the wind impacting the surface, thereby threatening life and property. Second, the density and configuration of a CASA network allows for better opportunity to measure the along-radial winds and thus, to better estimate the strongest wind velocities within a storm. Wind velocities can only be measured directly along the radial beam; wind velocities perpendicular to the radar beam cannot be measured. When a storm moves perpendicular to the beams of a WSR-88D, wind velocities may be underestimated. However, with a CASA network, multiple radars with overlapping beam coverage provide multiple angles of measurement, providing 3D imagery of the storm velocities.

A severe wind event from June 20, 2007, highlights the advantages provided by the CASA network (Figure 6). The CASA radar beam observes the storm at a lower elevation than NEXRAD, thereby better representing the wind impacting the surface. The CASA beam also measures directly parallel (along the path) to the maximum wind velocities, more accurately estimating the maximum wind speeds. In this example, maximum wind speeds estimated from the WSR-88D were ~ 50 mph; CASA-estimated maximum wind speeds were 65 mph. The maximum wind measurements at the ground were 63 mph.

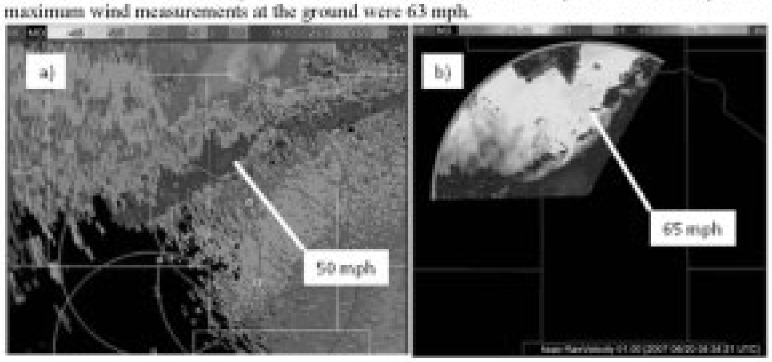

Figure 6: a) Wind velocity measurement from KTLX (WSR-88D); b) Wind velocity measurement from KSAO (CASA).

Tornadoes

Tornadoes present a problem to forecasters because of their relatively small size and rapid formation and dissipation. CASA radars provide very high spatial and temporal resolution data sampled near the surface, making them ideal tools for monitoring and tracking tornadoes. A rotating supercell thunderstorm on May 8, 2007, highlights the advantages offered by CASA (Figure 7). Data from the WSR-88D are updated every 5-6 minutes with relatively coarse resolution. CASA data are updated once per minute, giving forecasters much greater insight into the evolution and trends of storms and tornado development. The high resolution imagery provides forecasters with highly detail storm structure information.

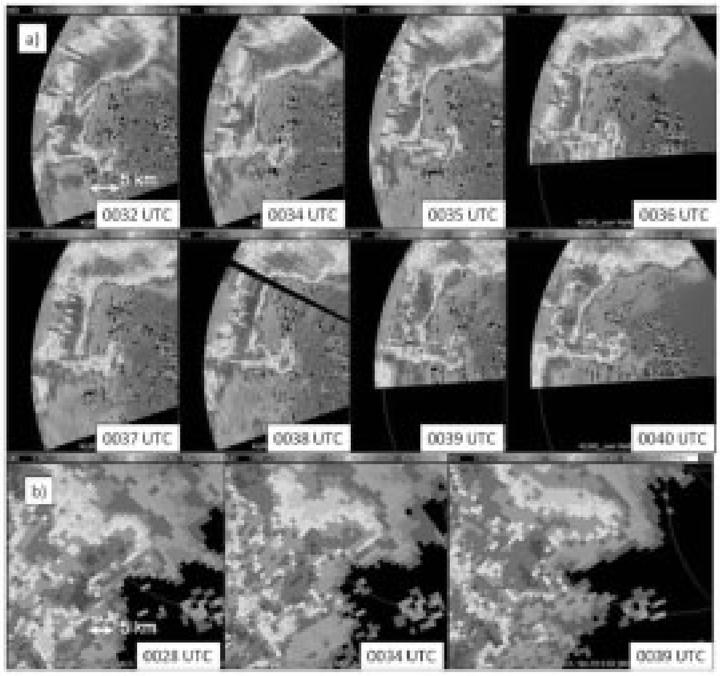

Figure 7: a) Time series of reflectivity data collected at 1.0 deg elevation from the CASA radar near Lawton (KLWE) between 7:32 CT and 7:40 CT May 8, 2007. b) Level 3 reflectivity data collected at 0.5 deg elevation from the WSR-88D radar near Frederick, Oklahoma (KFDR) between 7:28 CT and 7:43 CT 8 May 2007.

Combining CASA data with GIS information further enhances its utility (Figure 8). With increased resolution, warnings can be made more specific, reducing false alarms for areas not threatened and focusing alert systems. Overall, operational forecasters achieve a much greater confidence in their warning and monitoring capabilities with increased low-level sampling in space and time.

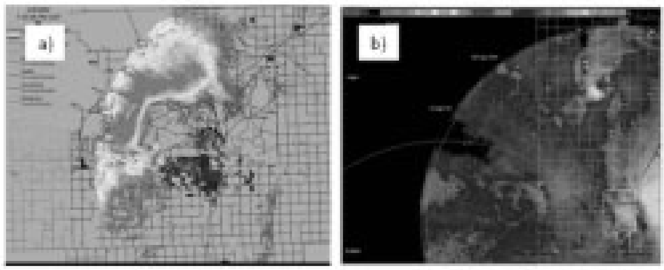

Figure 8: The high temporal and spatial resolution of CASA data combined with high-resolution GIS overlays of road and political boundaries improves tornado tracking. a) CASA reflectivity of a supercell moving north through the Lawton metropolitan area May 8, 2007. b) CASA velocity data of a supercell moving northwest through rural Minco, OK, May 8, 2007.

Forecasting

The best way to reduce the threat to public safety and property from severe wind is to provide stakeholders with long-term warnings of an hour or more. Known as "Warn on Forecast", future storm warnings will likely be issued based on numerical weather prediction forecasts, even before storms develop. While this technology is not yet available, initial experiments show that low-level radar data, such as provided by CASA, may be necessary in order to accurately predict the proper formation and timing of tornadoes.

Mesoscale numerical models require radar data to properly initialize and more accurately predict storm development (Brewster et al. 2008). Initialization of a numerical model using only WSR-88D data often leaves gaps at low-levels where the NEXRAD radars cannot observe (e.g., Figure 9a). However, CASA radars observe at low-levels, and so assimilating data from both CASA and NEXRAD can fill-in these gaps, providing complete data information throughout the model domain (Figure 9b). Thus, model forecasts are improved with more complete initialization.

An example of a forecast of a tornado from May 8, 2007, demonstrates the value of this improved initialization using CASA data (Figure 10). Two 80-minute forecasts were run; the first forecast assimilated only WSR-88D data (Figure 10a), while the second forecast assimilated both WSR-88D and CASA radar data (Figure 10b). The location of the observed tornado is marked with a blue triangle. The WSR-88D only forecast run did not predict any strong low-level rotation near the site of the observed tornado. However, the WSR-88D+CASA data forecast produced strong rotation in the immediate vicinity of the observed tornado, 80 minutes in advance.

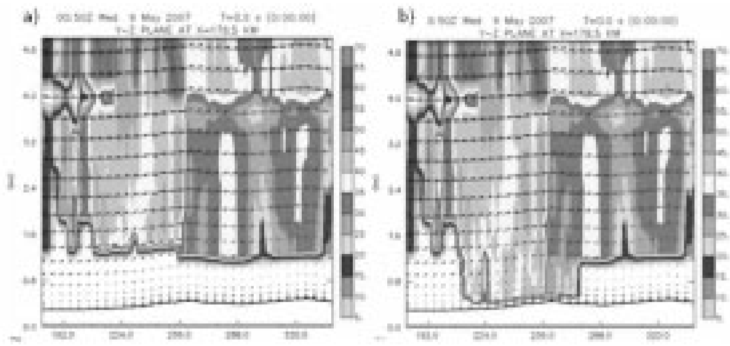

Figure 9: A cross-sectional slice (X-Z plot) showing radar reflectivity. a) Data assimilation including only WSR-88D data. b) Data assimilation including data from WSR-88D and CASA radars. Note the data gap between 0 and 1 km AGL (0 to 0.6 miles AGL); inclusion of CASA data fills in that data gap (Brewster et al. 2008).

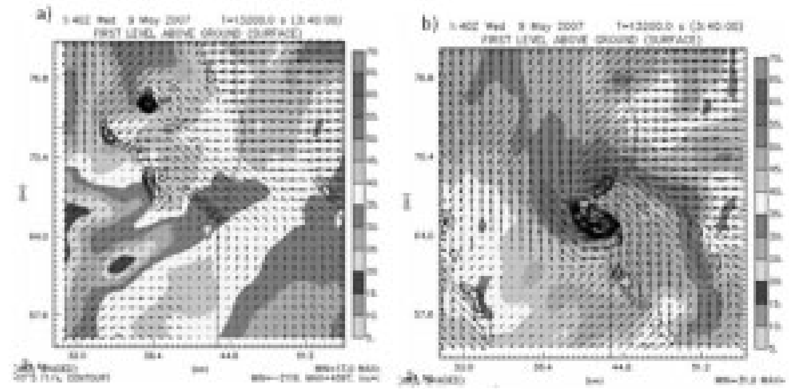

Figure 10: A mesoscale model forecast with and without CASA data assimilated. The blue triangle represents where an observed tornado touched down; contours represent model forecast vorticity. a) An 80-minute forecast assimilating only WSR-88D data; no strong circulation features are observed near the observed tornado. b) An 80-minute forecast assimilating WSR-88D and CASA data; a strong circulation vortex is forecast very near where the tornado was observed (Brewster et al. 2008).

Summary

CASA and MPAR are creating an end-to-end observing system based upon the needs of end-users. Together, these radar networks provide rapid, adaptive, high-resolution, overlapping beam coverage at high-, mid-, and low-levels, in order to best observe and forecast atmospheric phenomena, such as severe storm winds and tornadoes. Continued advances in research by CASA and MPAR are expected to further enhance adaptive sensing capabilities, while increasing public safety and warning potential.

For more information, please visit the CASA and MPAR web sites at http://www.casa.umass.edu and http://www.nssl.noaa.gov/divisions/radar/par/mpar.php.

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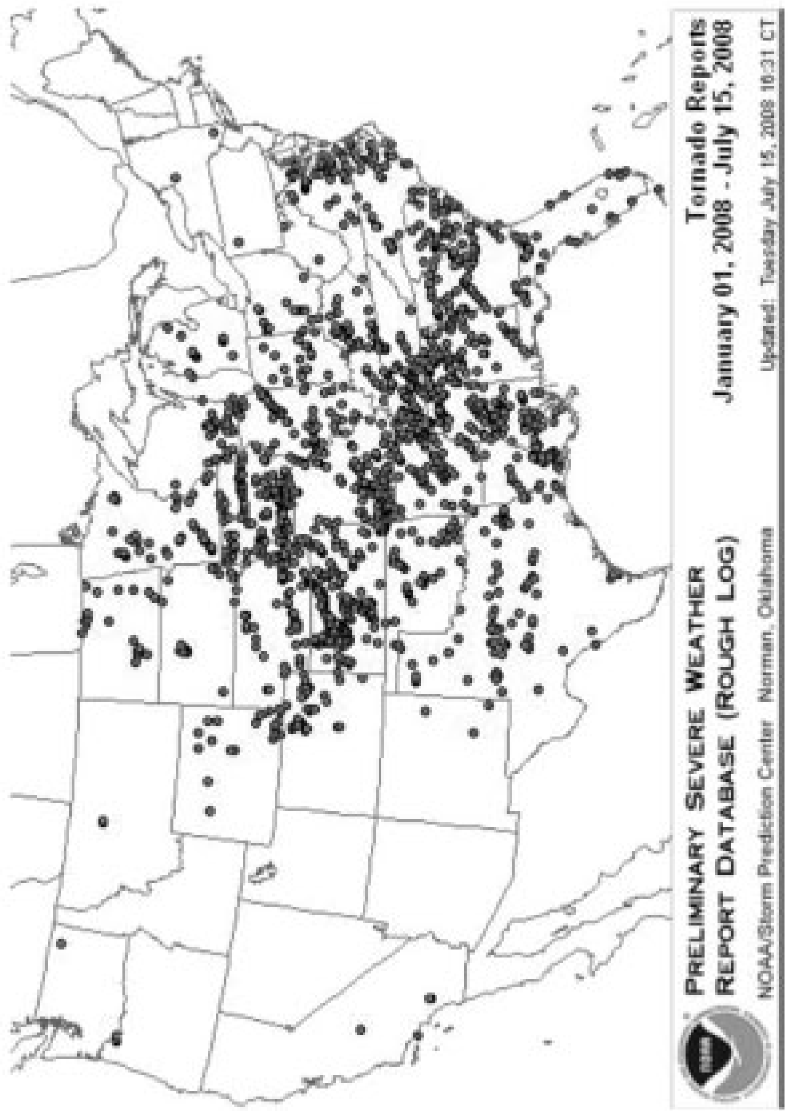
Preliminary Severe Weather
Report Database (Rough Log)
NOAA/Storm Prediction Center Norman, Oklahoma
Tornado Reports
January 01, 2008 - July 15, 2008
Updated: Tuesday July 15, 2008 16:31 CT

Impact of Tornadoes

In 2007, according to the National Weather Service, 111 Americans died in tornadoes and thunderstorm winds, and this year, tornadoes have already killed 119 people.

Year	Tornado Fatalities	Tornado Property Losses
2006	67	752.3
2005	38	421.8
2004	35	537.1
2003	54	1265.6
2002	55	801.3
2001	40	630.1
2000	41	423.6
1999	94	1989.9
1998	130	1714.2
1997	67	730.7
1996	25	719.6
	Total: 646	Total: 9986.2 M (USD)

Table 1. Fatalities, injuries, and property losses. Data compiled by the national Weather Service (available at: http://www.nws.noaa.gov/om/hazstats.shtml). Property losses reported in millions of USD.

STATEMENT OF DR. STEPHEN P. LEATHERMAN
CHAIR PROFESSOR AND DIRECTOR
INTERNATIONAL HURRICANE RESEARCH CENTER &
LABORATORY FOR COASTAL RESEARCH
FLORIDA INTERNATIONAL UNIVERSITY
MIAMI, FLORIDA

Florida International University (FIU) in Miami, Florida, urges Congress to promptly pass legislation to reauthorize the *"National Windstorm Impact Reduction Act of 2004."* The Committee is commended for recognizing the need to establish a national windstorm impact reduction program and for holding a hearing on this nationally important topic. FIU strongly urges Congress to take prompt action so that reauthorization of this Act can occur during the 110th Congress before its 2008 authorization expiration.

We are heartened, thanks to the efforts of Reps. Debbie Wasserman Schultz (FL) and Dennis Moore (KS) that the FY '08 Commerce, Justice Science Appropriation Conference Report includes $11.3 million to implement the *National Windstorm Impact Reduction Act.* We are disappointed that neither the National Oceanic and Atmospheric Administration, the National Institute of Standards and Technology, nor the National Science Foundation have chosen to fund the Act as directed by the Commerce, Justice, Science Appropriations Subcommittee, presumably due to budget shortfalls and different priorities. FIU strongly urges the Committee to advise these agencies of the importance of the *National Windstorm Impact Reduction Act* and to make implementation of the 2004 law a high agency priority. Likewise, FIU strongly believes in the need for coordinated programs at the federal level to reduce the impacts of hurricanes and other windstorms.

If a hurricane of the same category as Hurricane Andrew (which hit South Florida in 1992) would hit Miami directly, it would be a $100+ billion disaster, comparable to the physical damage New York suffered as a result of 9/11. While the size of the national hurricane mitigation research program that the National Science Board outlined is significant, it only represents one percent of the present value of the damage caused by Hurricane Andrew. Our research shows that funding for a strong, coherent and united research agenda could lead to significant loss reductions in structural damage as well as lives saved.

Florida International University—Miami's public research university—established in 1972, has more than 38,000 students, almost 1,100 full-time faculty and more than 124,000 graduates, making it the largest university in South Florida and placing it among the Nation's 25 largest colleges and universities. FIU offers more than 200 baccalaureate, Master's and doctoral degree programs in 21 colleges and schools. Research is emphasized as a major component of its mission. The University is ranked as a Research University in the High Research Activity category of the Carnegie Foundation's prestigious classification system. FIU's College of Law received full accreditation in 2006, and it led all universities in the state with the highest pass rate of 94.4 percent on the 2007 statewide Florida Bar Examination. In the Fall of 2009 we will be welcoming our first medical school class.

FIU is an active member of the national Wind Hazard Reduction Coalition, but as Director of FIU's International Hurricane Research Center, the state-wide center for hurricane research in Florida, my statement will reflect our unique university perspective, largely as it relates to hurricanes. Before commenting on the need to reauthorize the 2004 National Windstorm Impact Reduction Program, I wish to acquaint you with the work underway at the International Hurricane Research Center and to explain why it is in the national interest, and indeed the interest of the Federal Government, to support the development and implementation of a rational research strategy, focusing on the reduction of future hurricane and other windstorm damage.

INTERNATIONAL HURRICANE RESEARCH CENTER

The International Hurricane Research Center (IHRC) at Florida International University (FIU) conducts basic and applied multi-disciplinary scientific research to reduce the potential for damage from hurricane impacts to the natural and built environments in vulnerable communities throughout the United States and in other countries. It was established by the private sector in the aftermath of Hurricane Andrew.

As Florida's center for hurricane research, education and outreach, the IHRC offers a solid record of interdisciplinary and collaborative research, both basic and applied, focusing on the full spectra of hurricane impacts and the methods and techniques for hurricane loss reduction. The work of the IHRC has largely involved Florida and the larger Caribbean and Gulf basin, where most of the North Atlantic hurricanes make landfall.

The knowledge and findings resulting from the work of the IHRC, and the complementary education and outreach programs, benefit not only Florida and specific countries in the Caribbean and Latin America, but every hurricane vulnerable community in the USA and abroad. These capabilities clearly allow the IHRC to support federal strategic objectives and priorities, providing increased assistance to international partners while concentrating on the domestic front.

In fulfillment of its mission, the IHRC has engaged in a wide-ranging research agenda that includes the following areas:

- *Research and development of effective and credible hurricane loss reduction methods and techniques for housing in Florida.* This involves the testing of various building components and assemblies, development of improved building design criteria, and the analysis of various architectural and structural elements and their role in modifying the performance of buildings under hurricane conditions. IHRC researchers have developed an innovative full-scale structural testing facility—the Wall of Wind—to determine inherent weaknesses of structures when subjected to hurricane-force winds and rain. This research facility, the first-of-its-kind, will revolutionize our building construction and retrofitting practices. (Funded by Florida Department of Community Affairs, Florida Division of Emergency Management, National Science Foundation, Florida Sea Grant, Renaissance Reinsurance Holdings, Ltd, and AIR Worldwide.)
- *Development of a public domain hurricane loss model to assess risk and estimate potential losses.* This integrated catastrophe (Cat) model is particularly useful to insurers, re-insurers, regulators as well as the financial and housing industries. The model includes newly-developed knowledge databases and an updated wind field model. (Funded by Florida Office of Insurance Regulation.)
- *Implementation of a windstorm simulation and modeling.* This project focuses on the use of high-resolution data acquisition with airborne LIDAR technology and IHRC-developed algorithms, enhanced storm surge modeling, computer simulation and visualization complemented by public education and outreach programs. (Funded by the Federal Emergency Management Agency and National Oceanic and Atmospheric Administration.)
- *Assessment of beach erosion, sea level rise impacts and coastal vulnerability.* This project uses high-resolution elevation data and modeling to assess coastal vulnerability at specific locations. (Funded by National Oceanic and Atmospheric Administration and The Andrew W. Mellon Foundation.)
- *Assessment of social consequences and the human impact of hurricanes.* Evaluation of how various social factors such as demographics, socioeconomic strata or education may affect perceptions and attitudes influencing critical issues such as hurricane evacuation and the use of mitigation measures. (Funded by the National Science Foundation, National Oceanic and Atmospheric Administration, and Florida Division of Emergency Management.)

To complement its research program, the IHRC also engages in efforts of education and outreach to transfer critical knowledge and findings to potential users and policy-makers in various fields. This includes *Developing a Culture of Mitigation* through education projects and television programs.

WINDSTORM VS. EARTHQUAKE RESEARCH

The National Windstorm Impact Reduction Program of 2004 is similar in many respects to the National Earthquake Hazards Reduction Program, which is regularly reauthorized by this committee and funded by Congress. However, hurricanes and other windstorms are the most devastating and damaging natural hazards impacting the United States and its territories in the Caribbean and Pacific basins.

The unavoidable seasonality of hurricanes and other windstorms and the damage they cause underscore our vulnerability to this awesome force of nature. Hurricanes alone cause tens of billions of dollars in damage annually, which represent 65 percent of insured losses from natural hazards in the U.S. over the past half century. Inexplicably, the Federal Government has focused on earthquake research and mitigation with comparable little funding for hurricanes. FIU urges Congress to recognize the significant damage caused by hurricanes and other windstorms each year and to similarly make research and mitigation for these natural disasters a high priority.

Extreme hurricane events in recent years (i.e., Andrew, 1992; Opal, 1995; Floyd, 1999; Ivan, 2004; and Katrina, 2005) have, with an increasing sense

of urgency, reinforced the proposition that the Nation must continue to work on, but also move beyond weather prediction and evacuation to achieve significant damage reduction. Against this background, increasing population and urban development in coastal areas highlight the dynamic nature of our vulnerability to hurricanes and the urgency of the problem. According to the 2000 census, population has increased by 20 percent (11.7 million people) in the most vulnerable states over the last ten years. This trend is predicted to continue.

Mitigation offers the best alternative for reducing potential damages from hurricanes and other windstorms. Merely being prepared to respond to the inevitable damage that will occur from storms does nothing to reduce the ultimate cost of these dangerous events. Effective mitigation to build a solid foundation for policy-making and construction practices can only be achieved through increased research, vulnerability assessments, education and outreach. Hurricane and other windstorm mitigation must continue to evolve by including not only a wide range of damage reduction tools such as improved building design and structural engineering methods, new construction technologies and materials, land use strategies, and building codes, but also new methods of data collection, improved communication technology, computer modeling, simulation and visualization.

It is in the national interest, indeed the interest of the Federal Government, to support the development and implementation of a rational research strategy, focusing on the reduction of future hurricane and other windstorm damage. Building upon current programs and other initiatives with shared objectives, this strategy will be based on leading academic research centers with the single focused goal of reducing the cost of hurricane impacts to the Federal, State, and local governments, as well as to businesses and households.

To contribute to the development and implementation of a strong, coherent and united research agenda focusing on hurricane loss reduction, the IHRC at Florida International University (FIU) has brought together the wealth of existing capabilities and evolving expertise of the public universities in Florida into an integrated multi-year, multi-disciplinary cooperative research effort—the Florida Hurricane Alliance. This coordinated effort was launched in 2004 with funding from NOAA.

RATIONALE FOR REAUTHORIZATION OF THE 2004 IMPACT REDUCTION PROGRAM

Florida International University believes that reauthorization of the National Windstorm Impact Reduction Program of 2004 is essential as there is an important need for a coordinated program to reduce the impacts of hurricanes and other windstorms that account for the bulk of the economic damages from all natural hazards in the United States.

Hurricanes alone have resulted in tens of billions of dollars in damages annually on average over the last decade, and currently there is insufficient funding to reduce these levels of impacts, which will likely increase. FIU is concerned that because no new money is authorized by this legislation, federal agencies will continue to be reluctant to fund hurricane and other windstorm-related research and will resist implementing this new program.

Much of the development along the U.S. East and Gulf Coasts was constructed during a lull in hurricane activity. As we are now just 13 years in a 20- to 30-year cycle of increased Atlantic hurricane activity, FIU is concerned that funding for national windstorm and hurricane research and mitigation will become even more insufficient at a time when the losses from hurricanes and other windstorms will be increasing in the future years. FIU strongly encourages the Committee to authorize new funding for the wind hazard program. We believe that federal investment in this program will pay large dividends in the near-term. For example, the cost of Hurricane Andrew, which hit South Florida over a decade ago, was $30 billion dollars. That figure would be approximately $80 billion in today's dollars. Our research shows that funding for a strong, coherent and united research agenda focusing on hurricane loss reduction will lead to a significant reduction of this figure. We view reauthorization of this Act as a good first step, and offer our expertise and services to the Committee in this regard.

FIU strongly believes that any windstorm reduction program should include appropriate attention to social science research and implementation, such as emergency preparedness and response, public and governmental adoption of mitigation measures, and linking disaster recovery to mitigation. Lessons learned from the Earthquake Hazards Reduction Program have proved the importance of research into socioeconomic issues as essential to a successful hazard reduction program.

We support the Act's provision to establish a national advisory committee and are anxious to participate with the other key sectors to develop a comprehensive national windstorm mitigation program board based on the latest research and sound public policy strategies.

Finally, we believe that effective mitigation can only be achieved through increased research, vulnerability assessments, education and outreach. FIU reminds the committee of the unique contribution that the higher education community can play in helping to build a solid foundation for policy-making and for reducing potential impacts and damages from hurricanes and other windstorms.

While the *Windstorm Impact Reduction Act* was initially enacted in 2004, agencies did not pay attention to it. Attempts to obtain funding have worsened as time has passed. FIU feels that this reauthorization is of particular importance this year of predicted high-level hurricane activity as evidenced by four named storms so early in the season. The 2008 hurricane season is expected to have six to nine hurricanes, two of which being major hurricanes. FIU not only supports the reauthorization of this critical Act but urges the agencies to fund it.

Biography for Stephen P. Leatherman

Education

Ph.D., Environmental (Coastal) Sciences, University of Virginia, 1976

B.S., Geosciences, North Carolina State University, 1970

Publications

16 books and National Academy reports, including *Hurricanes; Sea Level Rise: History and Consequences;* and *Barrier Island Handbook.*

Over 200 journal articles and technical reports authored, including articles in both *Science* and *Nature.*

Expert testimony for the U.S. Senate and U.S. House of Representatives ten times.

On-screen host and co-producer, "Vanishing Lands" film, 1992, winner of three international film awards, including the Golden Eagle.

Professional Presentations

Over 200 speeches at national and international scientific conferences including Antigua, Argentina, Bahamas, Brazil, Canada, China, Denmark, Egypt, England, France, Hong Kong, Iceland, Ireland, Italy, Japan, Mexico, Micronesia, Netherlands, Norway, Puerto Rico, Thailand, Venezuela and Wales.

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